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BUILDING BACK A GREENER BANGLADESH

Country Environmental Analysis


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List of Acronyms

8FYP	8th Five-Year Plan
AAP	ambient air pollution
ADB	Asian Development Bank
ADP	Annual Development Programme
AF	attributable fraction
ALRI	acute lower respiratory infections
APCR	Air Pollution Control Rules
AQG	air quality guideline
AQM	air quality management
BAU	business as usual
BB101	CGE Bangladesh Bioeconomic 101
BB	Bangladesh Bank
BBS	Bangladesh Bureau of Statistics
BC	black carbon
BCIC	Bangladesh Chemical Industries Corporation
BCR	benefit-cost ratio
BDP	Bangladesh Delta Plan 2100
BDT	Bangladeshi taka (Tk)
BEPZA	Bangladesh Export Processing Zones Authority
BEST	Bangladesh Environmental Sustainability and Transformation Project
BEZ	Bangladesh Economic Zone
BEZA	Bangladesh Economic Zone Authority
BFD	Bangladesh Forest Department
BFIDC	Bangladesh Forest Industries Development Corporation
BFRI	Bangladesh Forest Research Institute
BFSIC	Bangladesh Sugar and Food Industries Corporation
BIWTA	Bangladesh Inland Water Transport Authority
BLL	blood lead level
BMBKEA	Brick Manufacturing and Brick Kilns Establishment Act
BPDB	Bangladesh Power Development Board
BSCIC	Bangladesh Small and Cottage Industries Corporation
BSEC	Bangladesh Securities and Exchange Commission
BSTI	Bangladesh Standards and Testing Institution
CASE	Clean Air and Sustainable Environment
CCDR	Country Climate and Development Report
CDC	US Centers for Disease Control and Prevention
CEA	Country Environmental Analysis
CETP	centralized effluent-treatment plant
CGE	computable general equilibrium
CH4	methane
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CMSMEs	cottage, micro, small, and medium enterprises
CNG	compressed natural gas
CO_2	carbon dioxide
CoED	cost of environmental degradation
COPD	chronic obstructive pulmonary disease
CSO	civil society organization
CVD	cardiovascular disease
DALY	disability-adjusted life year
DG	Director General
DoE	Department of Environment
DPC	Development Policy Credit
DPHE	Department of Public Health Engineering
EC	Environmental Clearance
ECA	Environment Conservation Act
ECC	Environmental Clearance Certificate
E. coli	Escherichia coli bacteria
ECR	Environment Conservation Rules
ECtA	Environment Court Act
EDTA	Ethylenediaminetetraacetic acid
EFSA	European Food Safety Authority
EIA	Environmental Impact Assessment
EIS	electric induction stove
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EMR	Hazardous (e-waste) Management Rules
EMS	Environmental Management System
EQS	Environmental Quality Standards
ES	electric stove
ESCAP	UN Economic and Social Commission for Asia and the Pacific
ESDO	Environment and Social Development Organization
ESP	electrostatic precipitator
ESRM	Environmental and Social Risk Management
ETP	effluent treatment plant
FAO	Food and Agriculture Organization
FGD	flue gas desulfurization
FI	financial institution
FY	fiscal year
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GBD	global burden of disease
GDA	Greater Dhaka Area
GDP	gross domestic product
GFVC	Green Financial Value Chain
GHG	greenhouse gas
gm	gram
GoB	Government of Bangladesh
Ha	hectare
HAP	household air pollution
HEI	Health Effects Institute
HWF	handwashing facility
I&M	inspection and maintenance
ICS	improved cookstove
ID	iron deficiency
IDCOL	Infrastructure Development Company Limited
IEE	initial environmental examination
IER	integrated exposure–response

IEUBK	Integrated Exposure Uptake Biokinetic
IGP	Indo-Gangetic Plain
IHD	ischemic heart disease
IHME	Institute for Health Metrics and Evaluation
IIASA	International Institute for Applied Systems Analysis
IPEN	International Pollutants Elimination Network
IQ	intelligence quotient
kWh	kilowatt-hour
LC	lung cancer
LDPE	low-density polyethylene
LFP	labor-force participation
LGI	local government institution
LMI	lower-middle income
LMIC	low- and middle-income countries
LMO	Living Modified Organisms
LPG	liquified petroleum gas
LSMGO	low sulfur marine gas oil
m	meter
mg/kg	milligram (one-thousandth of a gram) per kilogram
ml	milliliter (one-thousandth of a liter)
MICS	Multiple Indicator Cluster Survey
MJ	megajoule
MoC	Ministry of Commerce
MoEFCC	Ministry of Environment, Forest and Climate Change
MoF	Ministry of Finance
MoI	Ministry of Industries
MoIB	Ministry of Information and Broadcasting
MoLGRDC	Ministry of Local Government, Rural Development and Co-operatives
MoP	Ministry of Planning
MtCO2e	metric tons of carbon dioxide equivalent
NBR	National Board of Revenue
NCAPC	National Committee on Air Pollution Control
NCD	noncommunicable disease
NGO	nongovernmental organization
NH_3	ammonia
NHANES	National Health and Nutrition Examination Surveys
NIPORT	National Institute of Population Research and Training
NO_X	nitrogen oxides
O_3	ground-level ozone
O&M	operations and maintenance
PAF	population attributable fraction
Pb	lead
PES	Payment for Ecosystem Services
PFI	participating financial institution
PIF	potential impact fraction
PMF	positive matrix factorization
$PM_{2.5}$	particulate matter with diameter equal to or smaller than 2.5 micrometers (μm)
POP	persistent organic pollutant
POU	point of use
POUT	point-of-use treatment
ppb	parts per billion
PPM	primary $PM_{2.5}$
ppm	parts per million
PPP	purchasing power parity
RCT	randomized controlled trial
RECP	resource-efficient and cleaner production
RMG	ready-made goods
RR	relative risk
SAM	Social Accounting Matrix
SAR	South Asia Region
SD	standard deviation
SDG	Sustainable Development Goal
SEZ	special economic zone
SLCP	short-lived climate pollutants
SO_2	sulfur dioxide
SPM	secondary $PM_{2.5}$
SREDA	Sustainable and Renewable Energy Development Authority
SWM	solid waste management
SWMR	solid waste management rules
tCO2e	tons of carbon dioxide equivalent
TCS	traditional cookstove
Tk	Bangladeshi taka
TREL	theoretical minimum-risk exposure level
ToR	terms of reference
TSIP	Toxic Sites Identification Program
μg/dL	microgram (one-millionth of a gram) per deciliter
$\mu g/m^3$	micrograms (one-millionth of a gram) per cubic meter
ULAB	used lead-acid battery
UNICEF	United Nations Children's Fund
US	United States
USEPA	US Environmental Protection Agency
VOC	volatile organic compounds
VLSFO	very low sulfur fuel oil
VSBK	vertical shaft brick kiln technology
VSL	value of statistical life
WASA	Water Supply and Sewerage Authority
WASH	water, sanitation, and hygiene
WB	World Bank
WHO	World Health Organization
WSS	water supply and sanitation
WTP	willingness to pay
YLD	years lived with disability

Note: All dollar ($) amounts are in US dollars except when specified otherwise.

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Executive Summary

The 2023 Country Environmental Analysis (CEA) aims to support the Government of Bangladesh (GoB) in informing policies and investments for improving environmental health and pollution management, a critical step towards a green growth pathway. The CEA report focuses on (a) identifying the environmental priorities of the country and assessing how they affect health and productivity; (b) identifying interventions to tackle those priorities; (c) assessing the strengths and shortcomings in the country's environmental governance framework to address the environmental priorities and implement the proposed interventions; and (d) based on that analysis, making recommendations to strengthen governance and agencies' institutional capacity for environmental management.

Over the past two decades, Bangladesh made substantial economic progress as one of the world's fastest-growing economies, having reached lower-middle-income (LMI) country status in 2015 and being set to move off of the United Nations' Least Developed Country Index in 2026. However, the COVID-19 pandemic, followed by a sharp rise in global commodity prices and monetary policy tightening in advanced economies, decelerated the Bangladesh's economic growth and increased the poverty rate for the first time in decades.

Bangladesh's development pathway has occurred at the expense of public goods, with negative externalities that affect the health, productivity, and welfare of the Bangladeshi people, particularly the poor and the most vulnerable groups. Intensive manufacturing and rapid urbanization, coupled with limited institutional capacity for environmental governance, have resulted in severe environmental degradation, natural resources depletion, and increased vulnerability to climate change.

In Bangladesh, the exposure to environmental health risk factors is at critically high levels. Four major environmental health risks were associated with over 272,000 premature deaths and 5.2 billion days lived with illness, which has an annual cost equivalent to 17.6 percent of GDP in 2019. The highest impacts are due to ambient air pollution (AAP) and household air pollution (HAP), responsible for nearly 55 percent of the deaths. These two factors should be established as the highest environmental priorities. Unsafe drinking water, poor sanitation, and hygiene; and lead exposure also represent pressing challenges, having caused approximately one-fourth and one-fifth of total deaths, respectively. Despite substantial declines in lead exposure over the last two decades, blood lead levels (BLLs) in children and adults remain at very high levels, and 17 percent of the population relies on drinking water with arsenic concentrations above the WHO guideline of 10 ppb. Lead exposure is estimated to have impaired intelligence among children, amounting to an annual loss of nearly 20 million IQ points.

Environmental pollution limits the country's human capital formation and retention and affects city attractiveness and competitiveness by reducing livability and productivity. Environmental impacts pose a disproportional burden on the poorest and most vulnerable groups, such as women, elders, and children under five years old, who suffer long-lasting health effects (including impacts on their cognitive development and productivity). These groups have limited resources to cope with the impacts of pollution on their livelihoods. Additionally, internal climate and rural-urban migration is adding pressure on cities, with increased traffic, noise and air pollution, and higher demand for essential services such as water supply and sanitation, solid-waste management, energy provision, and health services, which are already constrained, especially for the most disadvantaged groups and during extreme climate events.

Bangladesh faces other environmental and natural resource issues, such as river pollution and salinity intrusion, soil degradation, biodiversity loss, high exposure to mercury and heavy metals and noise pollution. Plastic-waste management is particularly challenging in the country. Plastic waste is mostly burned or openly dumped together with other solid waste streams, leading to increased flooding and river pollution, damage to ecosystems, and health risks such as vector-borne diseases and illnesses from air pollution. Since rivers discharge into the sea, plastic pollution in waterways is directly linked to marine pollution.

The CEA assessed potential solutions to prevent and mitigate the impacts of Bangladesh's major environmental health risks. A benefit-cost analysis helped identify appropriate interventions that promised the greatest control of impacts by presenting benefit-cost ratios (BCRs)[1] of alternative policies and investments. Implementation of the following interventions (all with BCRs greater than one) is estimated to prevent over 133,000 premature deaths per year, among other benefits:

- **Ambient and household air pollution control interventions.** Comprehensive measures can, if fully implemented, reduce ambient $PM_{2.5}$ by as much as 33 percent by 2030. Priorities for such control measures include the following: (a) replace household use of solid fuel for cooking by switching to liquefied petroleum gas (LPG) or electricity; (b) control emissions from industry and the power sector; (c) eliminate the burning of waste; (d) improve management of agricultural fertilizers and livestock manure; and (e) collaborate with neighboring countries to address transnational $PM_{2.5}$ pollution. The most effective intervention to improve ambient $PM_{2.5}$ is the reduction or elimination of solid fuel for cooking by households switching to LPG or electricity, which has the added benefit of reducing the health effects of HAP. Other priorities for HAP control measures are to (f) further assess the potential for promoting the use of electric stoves for cooking, and perhaps especially induction stoves, a cheaper option than LPG for small users of electricity that can benefit from lower residential block tariff rates for electricity, and (g) further assess price and non-price obstacles and incentives for adoption of LPG for cooking. In the transition to cleaner fuels for households, continued expansion of improved cookstoves programs (particularly the promotion of dual-burner stoves) will continue to be important for households that cannot afford cooking with LPG or electricity. In parallel, health policies are needed to (a) enhance curative care of health problems brought on by air pollution, and (b) gather community-level data on the health issues in air pollution hotspots, coupled with meteorological and air quality data, to inform policy decision-making.
- **Lead exposure control interventions.** Because of data constraints on the sources of lead, three provisional interventions were considered to mitigate lead exposure and impacts. The following interventions should be prioritized: (a) supplement iron for children ages 6 to 59 months; (b) replace lead-contaminated cookware made from recycled aluminum; and (c) rehabilitate abandoned used lead-acid battery (ULAB) recycling sites. The main benefit of these interventions is increased lifetime income from averting IQ losses in early childhood. To address the challenges of lead pollution and population exposure, which will still take time to solve, priority should also be given to (d) undertaking representative BLL measurement studies along with identification of sources of lead exposure, which will inform further policy formulation; (e) building the country's laboratory capacity for measuring BLL and testing lead in food and other products; and (f) enhancing coordination across environmental, health, food safety and consumer agencies to improve data management and policy formulation and to build awareness of lead poisoning and prevention measures among key stakeholders such as health providers and community leaders.
- **Water, sanitation, and hygiene (WASH) interventions.** The interventions with the highest BCRs for addressing microbiological pollution that should be prioritized are (a) household point-of-use treatment of drinking water with ceramic filter; (b) safely managed improved non-shared sanitation for households currently having unimproved sanitation; and (c) promotion of handwashing with soap targeting caregivers of children under five. Further measures that should follow are (d) safely managed improved non-shared sanitation for households currently sharing sanitation with other households; and (e) promotion of handwashing with soap to all household members. For mitigating exposure to arsenic in drinking water, three control interventions should be prioritized: provision of deep tube wells, ponds with sand filters, and household filtering, such as the SONO filter that uses iron and sand filtration. Further analysis is needed to assess the impacts of other highly poisonous heavy metals in water, such as lead, mercury, and cadmium.

Additionally, the CEA used a computable general equilibrium (CGE) model to analyze the economic, distributional, and environmental effects of policy and investment options for the pursuit of Bangladesh's green growth objectives, particularly through interventions that could reduce air pollution and inadequate WASH. The model's results suggest that removing the present energy subsidies may be a first choice for a fiscal policy intervention, with beneficial effects on both efficiency and environmental protection, especially for air quality. The removal's impact on inclusiveness would also be beneficial if the policy is combined with a redistribution of government savings to the poor. Setting the stage for efficient carbon markets also appears to be a feasible policy for Bangladesh with several beneficial effects, especially if combined with suitable policies for redistribution to poorer households. The model's exercises also assessed investments in water-resources management, suggesting that such a program could be highly beneficial and mobilize local labor and other unemployed resources. In general, the CGE simulations indicated that those policy options may be reasonably effective in generating benefits (reduction of externalities), increasing GDP, and improving the condition of the poor. However, none of the fiscal and investment policy measures taken individually is likely able to sustainably increase incomes and reduce externalities. A combination of policy measures seems more effective than isolated interventions. In addition, command-and-control policies can be usefully complemented by fiscal and redistribution measures. Furthermore, compared to GDP, net social benefits tend to grow more than proportionally with policy combinations—and even more so if these policies include redistributive policies.

Since air pollution is the country's highest environmental priority, the CEA also assessed cost-effective measures to improve air quality in the Greater Dhaka Area (GDA), particularly to reduce human exposure to $PM_{2.5}$, the most harmful air pollutant for human health, to the WHO's annual Interim Target 1 of 35 µg/m³. Although this initial analysis could be refined with improved input data, it provides a solid basis to identify priority source sectors and interventions for emissions control, mainly due to their large emission-reduction potential. Priority sectors and interventions are (a) cleaner power generation; (b) universal access to clean cooking fuels; (c) separation of food waste, collection, and centralized composting in urban and rural areas; (d) enhanced PM controls at large industrial sources; (e) reduction of road and construction dust; (f) modern brick kilns, and (g) enforcing the ban on open burning of waste. For some sectors, the government has already issued regulations on emission standards, which will show some effect in the future. However, additional policies are needed to improve air quality in the GDA (and the country as a whole), moving beyond command-and-control interventions. A comprehensive program must include a portfolio of measures that deliver sufficient air quality improvements while being economically, socially, administratively, and politically acceptable. Because of transboundary emissions, cooperation with other districts in Bangladesh and countries of the Indo-Gangetic Plain is also indispensable for achieving substantial air quality improvements in the GDA. At the same time, regionally harmonized strategies could alleviate the need to take the GDA's most expensive measures.

Similarly, a holistic, integrated approach based on a combination of legal, financial, and communication instruments is needed to improve plastic-waste management. These measures should include (a) research and development of alternatives to single-use plastics; (b) effective implementation of the ban on plastic bags and extension of its scope to other single-use plastic items; (c) mandatory extended producer responsibility (EPR) guidelines to enable industry co-funding of plastic-waste collection and recycling systems and establish producer responsibility organizations (PROs); (d) an integrated waste-management framework to address growing plastic waste and disposal in open places; (e) waste segregation at the household level, development of missing infrastructure needed for such segregation, and implementation of behavior-change campaigns; (f) harmonization of plastic-management policies to promote circular economy; (g) plastic cleanup and recovery schemes to reduce legacy plastic waste and mitigate associated impacts; and (h) development of a monitoring system to implement the Solid Waste Management Rules 2021 and targets of the Plastic Action Plan.

Limitations in environmental policies—mostly of command-and-control and focused on environmental clearance—and weak enforcement have rendered Bangladesh's environmental management framework ineffective in reducing environmental degradation. Although a reasonably structured institutional framework is in place at the Ministry of Environment, Forest and Climate Change (MoEFCC) and the Department of Environment (DoE), their operation is hampered by (a) gaps in their organizational structure and environmental regulations; (b) insufficient budgetary and human resources; (c) large emphasis on environmental clearance and command-and-control policies; (d) capacity constraints for research, monitoring, and enforcement activities; (e) limited public participation and transparency in monitoring, oversight, and decision-making; (f) limited application of the polluter pays principle, with sanctions that are not able to deter polluting activities; (g) insufficient coordination among public agencies at the national and local levels; and (h) bottlenecks at environmental courts and delays in judicial cases.

Those constraints are coupled with insufficient incentives for citizens and businesses, such as access to green financing, research and development of green technologies, and awareness campaigns, to comply with environmental regulations and expand their market opportunities. Despite an explicit commitment to green growth in its 8th Five-Year Plan (2021-25) (8FYP), Bangladesh lags other emerging markets and developing economies in green finance due to structural weaknesses. Key stakeholders—such as borrowers, financial institutions (FIs), financial investors, consumers, and the government—still face several institutional bottlenecks and barriers in adopting and financing green practices.

Policy options to improve environmental quality and accelerate Bangladesh's transition towards green growth include the following:

- **Setting evidence-based priorities.** Bangladesh's environmental governance system shows a misalignment between the country's environmental priorities, institutional structure and efforts, and resource allocation. This is largely due to (a) the absence of an integrated system of reliable data and organizational capabilities to provide analytical support to the decision-making process, (b) the lack of representation of vulnerable groups that are mainly affected by environmental degradation, and (c) the absence of a formal planning mechanism for allocating financial and human resources according to clearly defined environmental priorities that are linked to poverty alleviation and social priorities. To address those challenges, the GoB needs to enhance its environmental monitoring and data-management capacity, including systematic evaluation of government interventions, networks for automated air and water-quality monitoring, outcome-oriented indicators to assess institutional performance, and adequate institutional presence in the field with sufficient and well-trained staff. Another key measure is to create a research and development unit at the DoE, which would conduct the analytical work in partnership with other government agencies to identify priorities and inform environmental planning—for example, through estimates of the cost of environmental degradation, cost-benefit analyses, and economic and distributional modeling.

- **Diversifying and strengthening environmental policy instruments.** As Bangladesh continues to develop its legal and institutional framework for environmental management, it should consider developing a wider range of environmental instruments, including (a) economic and market-based instruments, such as pollution charges, deposit-refund schemes, EPR, and final demand interventions; (b) litigation-based instruments, including liability legislation; and (c) information-based instruments, such as awareness campaigns and regular dissemination of environmental quality data and pollution loads, lists of highly polluting industries, and results of enforcement activities. These instruments could initially focus on identified environmental priorities and gradually expand to cover additional areas. In this process, the GoB should carefully assess the interventions' potential economic, social, and distributional effects, as well as identify mitigation measures for those impacts.

  As for command and control, a comprehensive amendment to the Environment Conservation Act (ECA) and its rules is needed to (a) modernize and make enforcement activities more efficient, including clear provisions to implement the polluters pay principle and set adequate sanctions and incentives for compliance with the ECA's provisions; (b) set the mandates and foundations for further regulations on EPR and payment for ecosystem services (PES); (c) mobilize green financing by establishing a permanent environmental fund, which could receive resources from the compensation for environmental damage envisaged in Article 7 of the ECA and eventually from environmental taxes; (d) improve stakeholder engagement in environmental decision-making; and (e) require Strategic Environmental Assessment for policies, plans, and programs, among other themes.

  As for the Environmental Clearance (EC) system, as a first measure, the DoE should conduct an in-depth, independent evaluation of Environmental Clearance Certificates (ECCs) approved for red and orange category projects, to extract common challenges and lessons to inform policy formulation—not only for improving the EC process, but also further regulate specific technical requirements. Although the ECR 2023 is expected to improve the EC process, additional amendments and guidelines are required to clarify and strengthen assessment criteria and procedures related to key themes— for example, the screening of projects that are not pre-categorized in the ECR; monitoring and enforcement after ECC issuance; stakeholder consultations and access to information, including through ICT tools.

- **Strengthening organizational structure and institutional capacity.** The GoB should carry out a detailed analysis of the organizational structure of the MoEFCC and affiliated agencies to set clearer mandates and more efficient processes for environmental governance, including interagency coordination. The DoE needs specialized technical units to respond to identified environmental priorities with the necessary human, technical, and financial resources to fulfill their mandates. The establishment of an environmental prosecution agency that is independent of the DoE and shielded from political interference must also be considered to make the environmental courts system more effective. To strengthen the capacity of environmental organizations to execute decisions, key measures include raising the DoE's budget (especially for monitoring and enforcement activities), establishing a cadre of environmental specialists, and increasing the DoE's headcount. This will allow more qualified professionals to reach senior official positions, attract and retain talented individuals, and ensure that decisions and policies are made by people with adequate backgrounds and experience. Completing the DoE's decentralization process is also essential to expand its physical presence to all districts, with adequate staffing, equipment, and budget, and to expedite actions and better balance the needs and priorities of central government officials and politicians with local stakeholders. For that, a comprehensive information-management system with automated monitoring for compliance and enforcement is essential for an effective decentralization process, as well as for gathering critical data to inform decision-making and public participation.

- **Strengthening citizen-driven accountability.** Responding to priority environmental challenges in Bangladesh calls for a more systematic effort to raise awareness of, and social accountability for, environmental issues. Also missing in the current institutional framework are mechanisms to incorporate the concerns of groups most severely affected by environmental degradation into the GoB's planning processes, as well as to allow citizens to directly litigate in environmental courts as plaintiffs—which requires amending the Environment Court Act. Ways to improve public information and promote transparency, accountability, and awareness include the publication of data in support of key environmental indicators (including pollution loads and environmental health statistics), wider use of public forums for air development initiatives, and broader and more detailed review and discussion of environmental management tools. Mechanisms to disseminate information in a manner that is easily interpretable can allow communities to serve as informal regulators.

- **Building an enabling environment for green financing.** To facilitate the flow of resources from green finance suppliers to sectors pursuing these resources, the GoB should create an environmental management ecosystem by (a) adopting a broad-based national green growth strategy and a national action plan backed by a commensurate set of regulatory and institutional frameworks; (b) constituting a high-level national oversight body to coordinate and monitor the progress of green growth efforts; and (c) creating an ecosystem of ministries and government agencies that collect and analyze point-source data to enforce policies that create a pipeline of verified investment-ready projects. Expanding its range of environmental policy instruments, the GoB should use a mix of incentives to boost environmental markets by (a) encouraging the adoption of green practices and promoting green businesses and investments with positive environmental externalities; (b) adopting incentives that address the risks faced by FIs; (c) fostering a collaborative institutional system to implement green financial incentives; and (d) reducing the risks perceived by financiers and boost private-sector adoption of green practices and technologies, and thereby boost the offering of green products and services. Strengthening institutional and borrower capabilities is also essential for building skills and expertise in green financing across sectors, from technocrats in government agencies to FIs, and from private businesses to students.

Endnote

1 BCR is the ratio of benefits to costs. A BCR greater than one indicates that the benefits are greater than the costs.

CHAPTER 1. INTRODUCTION

1.1 Country context

Bangladesh, the eighth most populous country in the world, is one of the world's fastest growing economies with substantial economic progress over the past two decades. Since 2000, income per capita has has tripled,, and the poverty rate has more than halved from 48.9 percent to 21.8 percent in 2018 (based on the national poverty line). Bangladesh reached lower-middle-income (LMI) status in 2015 and was set to move off of the United Nations' Least Developed Country Index in 2026.

However, the COVID-19 pandemic decelerated the Bangladesh's economic growth nearly and increased the poverty rate for the first time in decades. GDP growth fell from 7.9 percent in fiscal year 2019 to 3.4 percent in fiscal year (FY) 2020, as exports declined due to supply-chain disruptions and depressed external demand for ready-made goods (RMG) exports. Although Bangladesh seemed to recover rapidly from the COVID-19 pandemic, a sharp rise in global commodity prices and synchronized monetary policy tightening in advanced economies put that recovery at risk. Real GDP growth decelerated from 7.1 percent in FY2022 to an estimated 6.0 percent in FY2023, as high inflation weighed on private consumption and fiscal consolidation measures slowed government consumption and investment growth. Recovery is expected but will be gradual. The GDP growth is expected to decelerate in FY2024 before returning to its long-term trend.

Bangladesh's development pathway has occurred at the expense of public goods, with negative externalities that affect the health, productivity, and welfare of the Bangladeshi people, particularly the poor and the most vulnerable groups. Intensive manufacturing and rapid urbanization, coupled with limited institutional capacity for environmental governance, have resulted in severe environmental degradation, natural resources depletion, and increased vulnerability to climate change.

In Bangladesh, 3 in 10 children grow up stunted due to polluted water or lack of nutrition. In 2019, the health effects of ambient and indoor air pollution; lead exposure; and inadequate water, hygiene, and sanitation were responsible for 32 percent of premature deaths nationwide; 5.2 billion days lived with illness; and impaired intelligence among children, amounting to a loss of 20 million IQ points, according to this Country Environmental Analysis (CEA). Soil and water contamination, including from salinity intrusion and heavy metals, degrade natural resources essential for livelihoods and productive activities. The rivers surrounding the Greater Dhaka Area (GDA) receive about 60,000 meters per day of toxic industrial waste from more than 7,000 industries mainly located in nine major industrial cluster areas: Tongi, Hazaribagh, Tejgaon, Tarabo, Narayanganj, Savar, Gazipur, Ghorashal, and the Dhaka Export Processing Zone (Uddin and Jeong 2021). Soil pollution from industries is a major issue that also indirectly affects the rivers through groundwater flows and runoff during rainfall and flood events into the water bodies. Furthermore, chemicals used for agriculture are significantly polluting the soil. Inadequate waste management also contributes to the spread of vector-borne diseases, increased air pollutants and greenhouse gas emissions, and increased vulnerability to flooding. Depletion of the critical natural areas is also leading to a steady increase in the risk to flooding around the coastal areas, as well as infiltration of salinity into Bangladesh's surface and groundwater supplies (Sen and Ghorai 2019).

Those environmental impacts pose a disproportional burden on the poorest and most vulnerable groups, such as women, elders and children under age five years, who suffer from long-lasting health effects (including impacts on their cognitive development and productivity) and have limited resources to cope with impacts of pollution on their livelihoods. Therefore, environmental pollution limits their ability to overcome poverty and impairs the country's human capital formation and retention.

Pollution can also affect a city's attractiveness and competitiveness by reducing livability and productivity. Additionally, internal climate and rural-urban migration is adding pressure on cities, with increased traffic, noise and air pollution, and higher demand for essential services such as water supply and sanitation, solid-waste management, energy provision, and health services, which are already constrained, especially for the most disadvantaged groups and during extreme climate events. Without targeted policy action, increasing internal migration will exacerbate environmental degradation, affect climate-sensitive sectors, and further strain infrastructure and social safety-net systems (Rigaud et al. 2018).

Environmental degradation in Bangladesh is linked to constraints in environmental governance, such as (a) regulation gaps; (b) large emphasis on environmental clearance and command-and-control policies; (c) poor monitoring and enforcement capacity; (d) limited public participation and transparency in monitoring, oversight, and decision-making; (e) limited application of the polluter pays principle, with sanctions that are not able to deter polluting activities; (f) lack of coordination and clear mandates for environmental and climate-data management among public agencies; and (g) bottlenecks at environmental courts and delays in judicial cases. These constraints also affect business development by delays in environmental clearance processes, arbitrary decisions, lack of legal certainty, and lack of support to improve the environmental performance of local enterprises to access international markets.

In this context, a shift in Bangladesh's growth model is urgently needed to allow greener and more resilient development. The World Bank (2012) defines green growth as a growth pattern that is efficient in its use of natural resources; clean in that it minimizes pollution and environmental impacts; resilient in that it accounts for natural hazards and other shocks and the role of environmental management and natural capital in preventing disasters; and inclusive as it maximizes benefits for, and minimizes costs to, the poor and most vulnerable. Following a green growth strategy path for Bangladesh means that economic, social, and environmentally sustainable growth is achieved in a way that pursues poverty eradication and shared prosperity. Such a strategy will (a) ensure that natural resources and environmental services can sustainably fulfill their economic potential, and (b) tackle the increasing risks of shocks in an integrated manner and simultaneously ensure sustainability, resilience, and inclusiveness.

Channeling financing and policy shifts into a green growth approach can create a multiplier effect: reviving the economy, investing in projects to help Bangladesh prepare for the impending challenges of climate change while creating jobs, promoting low-carbon infrastructure, and building a more equitable society. Moreover, green growth is pivotal to ensuring that Bangladesh can decouple from its rather high carbon-intensive and relatively highly polluting, unsustainable growth path to one that is resilient and inclusive as Bangladesh endeavors to improve the quality of life and opportunities for all its citizens.

The Government of Bangladesh (GoB) has initiated such a transition, as envisaged in its major national development strategies. Bangladesh's 8th Five-Year Plan (2021-25) (8FYP) centers on six core themes, including "a sustainable development pathway that is resilient to disaster and climate change, ensures sustainable use of natural resources, and successfully manages the inevitable urban transition" (GED 2020). Over the medium term, the 8FYP targets comprehensive structural reforms to accelerate sustainable growth while building climate resilience across the economy, enhancing the provision of public services, especially for people living in poverty, and promoting a better-managed environment and natural resources to support productivity and growth.

Green, resilience, and inclusion elements are also embedded in the Bangladesh Delta Plan 2100 (BDP), a key instrument to address the sources of long-term climate-change vulnerability at source, thereby reducing the adverse effects of climate change on the population and generating co-benefits for environmental sustainability, job creation, and provision of essential services (GED 2018). The recently adopted National Adaptation Plan 2023–2050 (NAP) aims to build climate resilience while stimulating sustainable and inclusive economic growth. To achieve these goals, the GoB needs to further strengthen its regulatory framework and institutional capacity not only to manage negative environmental externalities from its rapid economic growth, but also to create opportunities for green jobs and new growth engines.

1.2 Objective

This CEA provides analytical underpinnings to inform policy reforms and investments for improving environmental health and pollution management, a crucial step towards Bangladesh's green growth pathway. The report focuses on (a) identifying the environmental priorities of the country and assessing how they affect health and productivity; (b) identifying interventions to tackle those priorities; (c) assessing the strengths and shortcomings in the country's environmental governance framework to address the environmental priorities and implement the proposed interventions; and (d) based on that analysis, making recommendations to strengthen governance and agencies' institutional capacity for environmental management.

1.3 Methodology

An interdisciplinary team prepared a series of background papers whose findings and recommendations are compiled in this CEA. As a first step, the team reviewed the 2018 CEA to identify critical themes to be updated and expanded in the current report, as well as the GoB's progress in implementing the recommendations (box 1.1). The 2018 CEA focused on urban areas, identifying challenges related to environmental degradation and analyzing the country's institutional framework for environmental management and green growth. The report outlined recommendations to improve policies, regulations, and institutional capacity in the areas of pollution management, resource efficiency, and environmental performance. The present CEA covers both urban and rural areas. Although it also focuses on pollution issues, the 2023 CEA expands the environmental governance analysis and, through a variety of economic analyses, the range of potential interventions to overcome environmental degradation.

The team used the Green, Resilient, Inclusive Development (GRID) benchmarking tool to assess Bangladesh's performance across four pillars (sustainability, efficiency, resilience, and inclusivity) in critical indicators against its development peers, aspirational targets, and the world. This exercise uncovered Bangladesh's deficiencies in all GRID dimensions, with the worst performance in indicators under the sustainability and resilience pillars: high mortality from air pollution, significant water-pollution challenges, high levels of deforestation, significant land degradation, high proportion of slum population, and high risk to assets, among others. The GRID benchmarking informed the selection of priority themes for developing the CEA. The CEA scoping was also informed by the report Breathing Heavy: New Evidence on Air Pollution and Health in Bangladesh (Raza et al. 2022), and the World Bank (2022b) report Striving for Clean Air: Air Pollution and Public Health in South Asia.

Box 1.1 Main developments since the 2018 CEA

The GoB incorporated some of the 2018 CEA recommendations in its 8FYP, highlighting its plans to (a) initiate environmental fiscal reforms to reduce pricing distortions that undermine sound environmental management; (b) improve monitoring of air and water quality, pollution emissions, and discharges; (c) expand public participation in environmental management; and (d) decentralize environmental management. The GoB has made progress implementing some of these plans. For example, the budget allocation to the Ministry of Environment, Forest and Climate Change (MoEFCC) has increased in the past three years after a reduction because of the COVID-19 pandemic. The MoEFCC has strengthened its regulatory framework by adopting, among other instruments, the 2023 Environment Conservation Rules (ECR), 2022 Air Pollution Control Rules (APCR), and 2021 Solid Waste Management Rules. The DoE has added a wing on chemicals and waste management to its organogram and expanded the number of district offices. With support from the World Bank-financed Bangladesh Environmental and Sustainability Transformation (BEST) Project, the DoE is expected to receive financial resources and technical assistance in the next years to (a) decentralize and increase the technical specialization of its organizational structure, including new local offices, environmental monitoring systems, and tools for disseminating environmental information; (b) recruit and retain qualified technical staff; (c) develop regulatory and policy reforms; and (d) create an endowment fund to mobilize sustainable financing for environmental conservation actions.

Going further in identifying the country's environmental priorities, the team estimated the costs of environmental degradation in Bangladesh. The analysis determined the focus of the CEA on pollution management, particularly air quality management. After identifying the major environmental challenges, the team conducted a benefit-cost analysis to compare—and assess the economic feasibility of—alternative interventions that are readily available to reduce the significant costs of environmental degradation, particularly household and outdoor air pollution, inadequate water, sanitation, and hygiene (WASH), and lead (Pb) contamination. For air pollution, the team also conducted a cost-effectiveness analysis of key interventions for the GDA. The team developed a computable general equilibrium (CGE) model to provide quantitative estimates on the environmental sustainability, economic contributions, and social implications of alternative policy scenarios that could improve air quality and WASH. Additionally, a review of the GoB's national development strategies and interviews with key stakeholders led to specific studies on plastic-waste management. Furthermore, an analysis of the country's environmental governance system aimed at identifying interventions to improve Bangladesh's institutional capacity to address its environmental priorities, including enhancing the environmental clearance system, diversifying policy instruments, and establishing the underlying conditions for green financing. The institutional analysis was informed by an overview of the country's framework for assessing and managing the environmental and social risks and impacts of development projects, taking the World Bank's Environmental and Social Framework as a benchmark.

The CEA also considered findings and recommendations from other World Bank-financed analytics, such as (a) the 2022 Bangladesh Country Climate and Development Report (CCDR) (World Bank 2022a), (b) the ongoing technical assistance (TA) to develop an Umbrella Investment Program (UIP) for the Dhaka Rivers, and (c) the upcoming Framework for Implementing Green Growth in Bangladesh (FIGGB) Report. The CEA recommendations to improve environmental governance, plastic-waste management, and WASH interventions are well aligned with the findings and recommendations of the UIP TA on industrial pollution in the GDA. Building on the CCDR recommendation of adopting a clean air program with climate co-benefits, the CEA provides key analytical underpinnings for selecting interventions and enhancing the institutional framework needed to design and implement such a program. In addition, the CEA complements the CCDR findings that underpin recommendations on (a) incentives for green financing, (b) energy-focused carbon tax, (c) phasing out fossil fuel subsidies, and (d) circular economy solutions for industries. The CEA also informed the FIGGB Report, as reflected in recommendations for improving environmental management and adopting specific policies for increasing efficiency and sustainability in key economic sectors, as well as setting the enabling environment for green financing.

1.4 Structure of the CEA Report

This CEA compiles the findings and recommendations of several papers and stakeholder consultations. The report is structured in eleven chapters as follows:

Chapter 1 introduces the report with information on the country context and the objectives, scope, and methodology of the CEA.

Chapter 2 estimates the health effects and corresponding costs of environmental degradation. The chapter focuses on (a) outdoor and household air pollution ($PM_{2.5}$), (b) lead exposure among children and adults, and (c) inadequate WASH, including arsenic contamination in drinking water and microbiological pollution.

Chapter 3 summarizes key institutions and regulations for environmental management in Bangladesh, especially policy instruments and agencies that are relevant to the country's environmental priorities. The chapter assesses the strengths and shortcomings of Bangladesh's environmental governance system, including mechanisms for planning and organizational performance evaluation, interagency coordination, environmental monitoring and data management, enforcement, accountability, transparency, and public participation.

Chapter 4 discusses the main elements of the environmental clearance system in Bangladesh, considering aspects such as the nature of environmental impact assessments, institutional leadership, and interagency coordination, screening and scoping processes, public participation, access to information, and evaluation of alternatives. The chapter assesses the adequacy of the environmental clearance system to address the country's environmental priorities.

Chapter 5 analyzes the costs and benefits of potential interventions to address household and outdoor air pollution; inadequate water, hygiene, and sanitation; arsenic contamination in Bangladesh; and lead exposure. Through this cost-benefit analysis (CBA), the chapter provides information for prioritizing interventions and better allocating the government's limited resources.

Chapter 6 analyzes air quality management in GDA and, through cost-effectiveness and CBA, identifies potential interventions to reduce human exposure to $PM_{2.5}$ to the WHO's Annual Interim Target 1 (35 ug/m^3) by 2030.

Chapter 7 discusses the prospects for green growth policies in Bangladesh that have the potential to tackle major environmental priorities—that is, air pollution and inadequate WASH. Through a CGE model, the chapter assesses potential economic, distributional, and environmental effects of the following policy experiments: (a) phaseout of energy subsidies, (b) carbon pricing (carbon tax and cap and trade system), and (c) investments in a water program (as envisaged in the BDP).

Chapter 8 provides an overview of the physical elements of Bangladesh's plastic-waste management system and outlines the key policy recommendations to support the transition to integrated plastic-waste management.

Chapter 9 identifies the barriers to accessing green financing, especially to address environmental priorities, and proposes interventions to facilitate the flow of resources from green finance suppliers to sectors pursuing such resources.

Chapter 10 identifies available environmental policy instruments, beyond traditional command-and-control, for improving environmental management in Bangladesh.

Chapter 11 summarizes takeaways from each chapter and recommendations for policy and investment options to strengthen governance and institutional capacity to support the transition towards a green economy.

Following the chapters is a set of 16 appendixes that provide greater detail on some of the topics covered in the main body of the CEA.

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CHAPTER 2. COST OF ENVIRONMENTAL DEGRADATION – ENVIRONMENTAL HEALTH ISSUES

2.1 Introduction

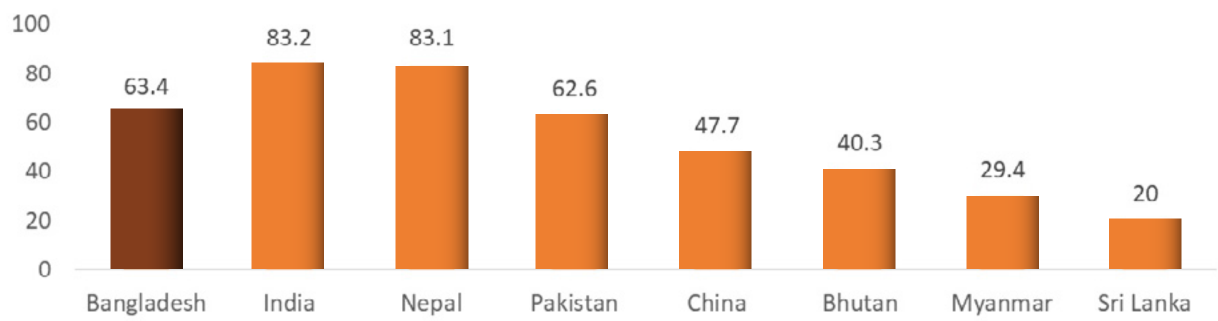
Pollution has substantial impacts on humans and the environment. This includes health impacts such as premature mortality, illness, and associated health-care expenditures and burdens on caregivers; children's nutritional status and cognitive development and associated learning productivity, school outcomes and lifetime earnings, and overall labor productivity; impacts on agricultural productivity; impacts on ecosystem services such as forest and water quality and associated effects on wildlife, timber and non-timber forest products, fisheries, and recreation and tourism; and effects on urban attractiveness, housing values, and competitiveness of cities. The health impacts of pollution have generally been found to constitute the largest share of the cost of pollution that can be quantified. Consequently, quantitative assessments of such health impacts can serve as an instrument to identify environmental priorities, mobilize support for their implementation, and move forward towards realizing environmental goals and objectives. Based on environmental issues raised by the Government of Bangladesh (GoB) and in literature review, this chapter estimates the main health effects in Bangladesh from key environmental health risks in 2019: outdoor ambient air pollution (AAP); household air pollution (HAP) from use of solid fuels; lead (Pb) exposure; and inadequate drinking water, sanitation, and hygiene (WASH) including arsenic in drinking water. Monetized estimates are provided of the social and economic cost of these health effects in taka and as a percentage of Bangladesh's GDP in 2019, using standard economic valuation techniques. These estimates have required a large amount of data and multiple methodologies that are summarized in appendix A.

Although this chapter focuses on those four major environmental health risks, Bangladesh faces other environmental and natural resources degradation issues, such as water pollution including river pollution and salinity intrusion, soil degradation, biodiversity loss, exposure to mercury and other heavy metals, and noise pollution. Further studies should be conducted to assess the costs and impacts of those environmental problems.

2.2 Ambient air pollution

Particulate matter (PM) and especially $PM_{2.5}$ is the outdoor ambient air pollutant that is globally associated with the greatest health effects.[2] Population-weighted ambient $PM_{2.5}$ in Bangladesh and nearby countries is presented in figure 2.1. Ambient $PM_{2.5}$ in Bangladesh was 63.4 μg/m³ in 2019. This is more than twelve times as high as WHO's annual air quality guideline (AQG) for $PM_{2.5}$ of 5 μg/m³ and nearly twice the WHO's first interim target and Bangladesh's standard of 35 μg/m³ for annual air quality (WHO 2021).

Figure 2.1 Population-weighted ambient $PM_{2.5}$ concentrations in Bangladesh and region in 2019 | *μg/m³*

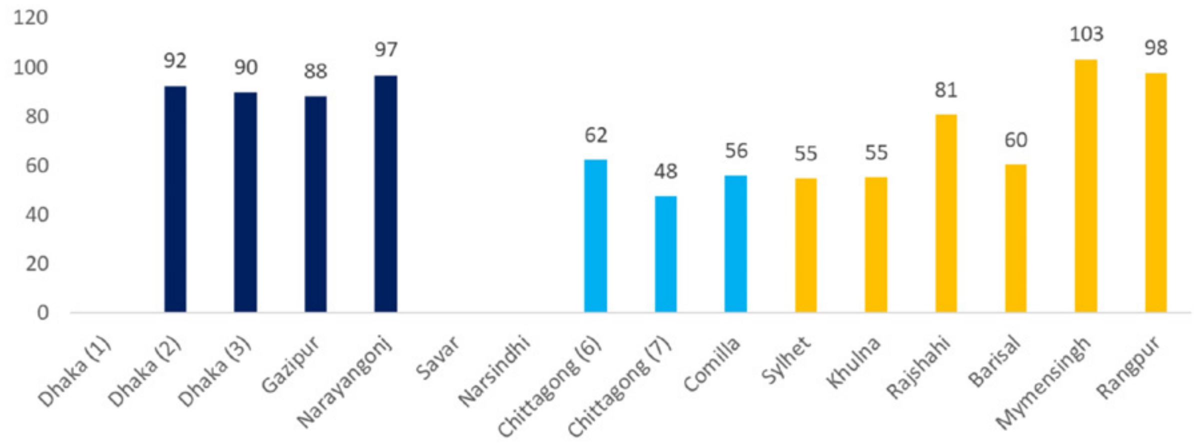


Source: HEI 2020.
Note: Data from Global Burden of Disease Study 2019.

2.2.1 Population exposure to ambient air pollution

Monthly average ambient $PM_{2.5}$ is reported in eight divisions in Bangladesh. The annual average $PM_{2.5}$ calculated from these monthly averages ranges from 48 to 103 μg/m³ (figure 2.2). This is 10–20 times the WHO AQG for annual $PM_{2.5}$.

Figure 2.2 Annual ambient $PM_{2.5}$ at monitoring stations in Bangladesh, 2019–21 | ***μg/m³***

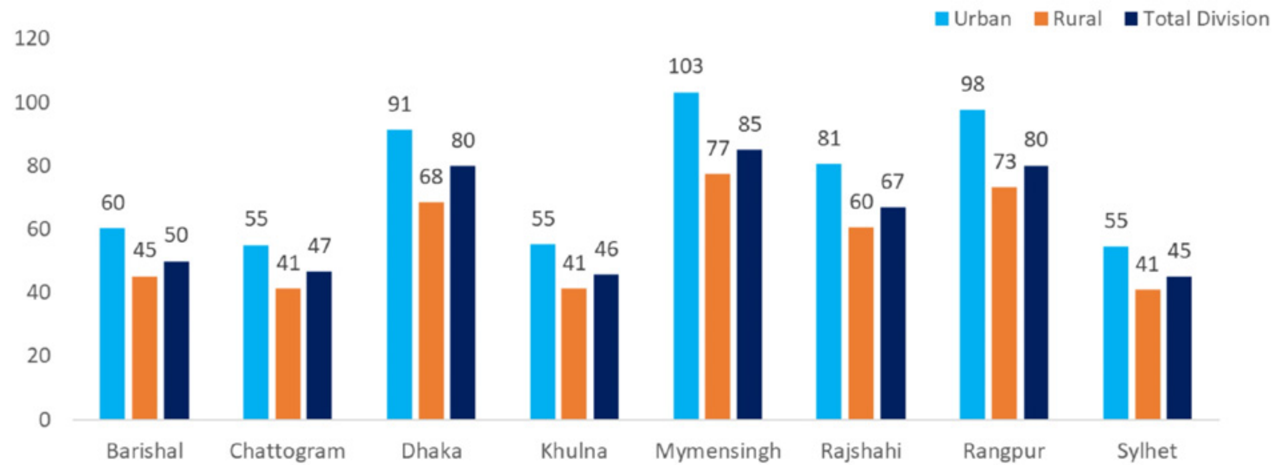


Source: Produced from data reported in the Monthly Air Quality Monitoring Reports by DoE, Bangladesh.
Note: Annual ambient $PM_{2.5}$ is calculated for the full twelve months of a year. Data from the COVID-19 lockdown periods of April, May, and June 2020 are not included. Ambient $PM_{2.5}$ during the lockdowns was substantially lower than during a normal year according to estimates by Qui et al. (2021).

The measurement data from the urban monitoring stations are used here as an approximation for ambient $PM_{2.5}$ in urban areas in the eight divisions. This results in population-weighted urban annual ambient $PM_{2.5}$ of 77 μg/m³. Measurements of ambient $PM_{2.5}$ in rural areas are practically nonexistent. Major sources of $PM_{2.5}$ in rural areas include emissions from burning of solid fuels by households for cooking and other domestic purposes; waste burning; and long-range emissions from urban areas within a division, from other divisions within Bangladesh, and from outside Bangladesh. The GBD 2019 reports population-weighted annual ambient $PM_{2.5}$ of 63.4 μg/m³ in Bangladesh in 2019 based on available urban $PM_{2.5}$ measurements at monitoring stations, chemical transport models, and nationwide urban and rural satellite imagery data (HEI 2020). This implies that population-weighted annual ambient $PM_{2.5}$ was 57 μg/m³ in rural areas, or 75 percent of annual urban ambient $PM_{2.5}$. Estimated annual ambient $PM_{2.5}$ by urban, rural, and total for each division is presented in figure 2.3.

The sources of the high ambient $PM_{2.5}$ concentrations in Bangladesh include typical sectors such as road vehicles, industry, and power plants; sectors that often receive less attention such as emissions from the burning of solid waste and emissions from household use of solid fuels for cooking and other domestic purposes that reach the outdoor ambient air; and $PM_{2.5}$ precursor emissions from fertilizer and livestock practices. Sources of ambient $PM_{2.5}$ in Bangladesh also include emissions originating from outside Bangladesh. This is discussed in chapter 5 and for the Greater Dhaka Area (GDA) in chapter 6.

Figure 2.3 Estimated population-weighted annual ambient $PM_{2.5}$ by division in Bangladesh, 2019–21 | *µg/m³*



Source: World Bank based on monitoring data from DoE.
Note: Data from the COVID-19 lockdown periods of April, May, and June 2020 are not included.

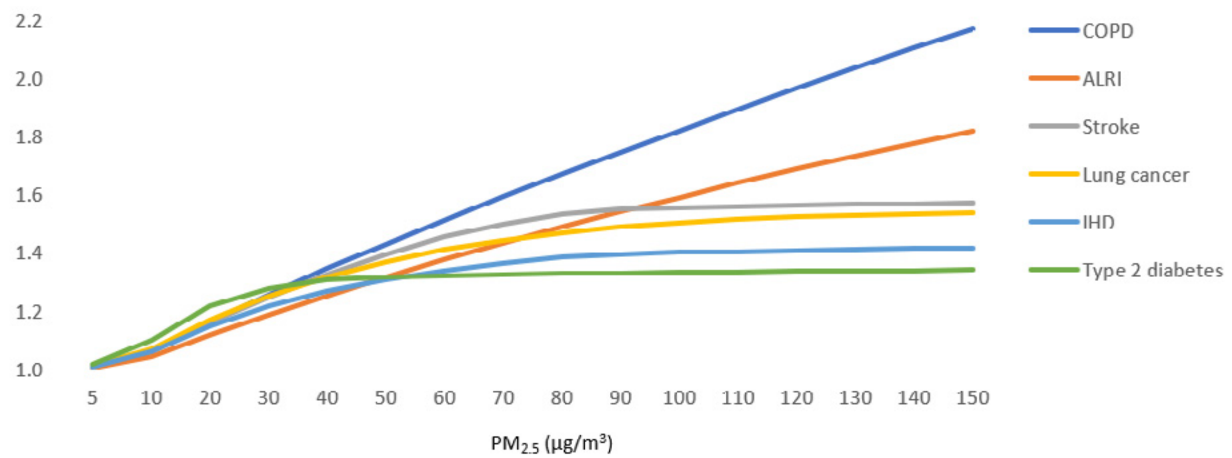
2.2.2 Health effects of ambient air pollution

The health effects of long-term exposure to ambient $PM_{2.5}$ include ischemic heart disease (IHD), cerebrovascular disease (stroke), chronic obstructive pulmonary disease (COPD), lung cancer, type 2 diabetes, acute lower respiratory infections (ALRI) and neonatal disorders. These are all major health effects evidenced by the GBD 2019 (GBD 2019 Risk Factors Collaborators 2020).

Figure 2.4 shows how the risk of death from the six main health effects increases with increasing levels of $PM_{2.5}$ exposure. The risks are substantial even at low concentrations of ambient $PM_{2.5}$ and increase rapidly for exposure levels up to 70–90 µg/m³ for all health outcomes except for type 2 diabetes, which flattens out from 35 µg/m³. The risk continues to rise linearly for COPD and ALRI even beyond $PM_{2.5}$ of 90 µg/m³.

Annual deaths from $PM_{2.5}$ exposure in each of the eight divisions in Bangladesh are estimated from the population-weighted annual ambient $PM_{2.5}$ in each division in figure 2.3 and the risks of health effects in figure 2.4 (see methodology in appendix B).

Figure 2.4 Relative risk of mortality from long-term exposure to $PM_{2.5}$



Source: GBD 2019 Risk Factors Collaborators (2020) Supplement.
Note: RRs of IHD and stroke are age-weighted.

An estimated 87–95 thousand people died from ambient $PM_{2.5}$ air pollution in Bangladesh in 2019, with a central estimate of 91 thousand (table 2.1). About 63 percent of the deaths were from IHD and stroke; 28 percent from pulmonary diseases (COPD, lung cancer, and ALRI); 5 percent from type 2 diabetes; and 4 percent from neonatal disorders. Ambient $PM_{2.5}$ also caused an estimated 245–266 thousand disability adjusted years of life lived with illness, corresponding to 1.1–1.2 billion days lived with illness. COPD, diabetes, and heart disease accounted for the largest shares of days lived with illness (table 2.2).[3] Health effects from ambient $PM_{2.5}$ during COVID-19 may have been somewhat less than in 2019 due to a lower amount of pollution-generating activities. Health effects likely increased again after COVID-19 along with economic recovery unless actions were implemented to reduce pollution.

Table 2.1 Estimated annual deaths from ambient $PM_{2.5}$ in Bangladesh, 2019

	Low	Central	High
Ischemic heart disease (IHD)	23,458	24,489	25,827
Stroke	31,419	32,824	34,648
COPD	14,808	15,247	15,773
Lung cancer	1,867	1,951	2,057
ALRI	8,153	8,390	8,672
Type 2 diabetes	4,387	4,576	4,822
Neonatal disorders	2,986	3,143	3,301
Total in Bangladesh	**87,079**	**90,620**	**95,099**

Source: World Bank.

Table 2.2 Estimated days lived with illness from ambient $PM_{2.5}$, 2019 | *Millions*

	Low	Central	High
IHD	292	305	322
Stroke	112	117	124
COPD	353	363	376
Lung cancer	0.67	0.70	0.74
ALRI	19	20	20
Type 2 diabetes	333	347	366
Neonatal disorders	0.43	0.45	0.47
Total in Bangladesh	**1,110**	**1,153**	**1,208**

Source: World Bank.

2.2.3 Cost of health effects of ambient air pollution

The cost of health effects of ambient $PM_{2.5}$ is estimated at Tk 1,291–1,409 billion in 2019, with a central estimate of Tk 1,343 billion (table 2.3). This cost is equivalent to 4.4–4.8 percent of Bangladesh's GDP that year, with a central estimate of 4.55 percent. Mortality accounts for 86 percent and morbidity for 14 percent of estimated cost (see methodology in appendixes H and I).

Table 2.3 Estimated cost of health effects of ambient $PM_{2.5}$ in Bangladesh in 2019 | *Tk, billions*

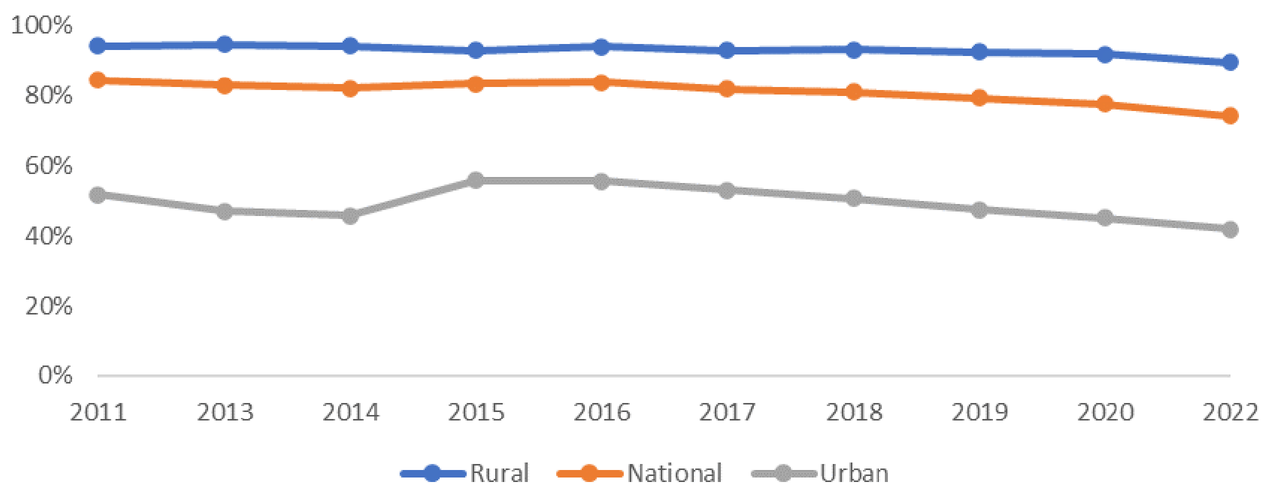
	Low	Central	High
Cost of mortality	1,105	1,150	1,207
Cost of morbidity	186	193	202
Total cost of health effects	1,291	1,343	1,409
Percent of 2019 GDP	4.38%	4.55%	4.77%

Source: World Bank.

2.3 Household air pollution

Household air pollution from the use of solid fuels for cooking and, in some climates for heating, is a major environmental health risk in low- and middle-income countries (LMICs). Seventy-four percent of the population in Bangladesh used solid fuels as primary cooking fuels in 2022 down from 84 percent in 2011 (figure 2.5). The decline in solid fuel use was particularly rapid from 2016 to 2022 at a rate of -1.6 percentage points per year, implying that 650,000 households have been switching to clean fuel and cooking technologies (LPG, gas, electricity) per year. The rate of decline in urban areas was three times faster than in rural areas. At these rates of decline 62 percent of the population will be using solid fuels as primary cooking fuel in 2030. The main solid fuels in Bangladesh are crop residue and wood. As many as 27–33 percent used crop residue and 38–48 percent used wood as primary cooking fuel as recent as 2019.[4] Available national surveys seem, however, to indicate a large decline in the use of crop residue as primary fuel in favor of wood from 2018/19 with the Bangladesh Population and Housing Census 2022 reporting 10 percent of households using crop residue and 59 percent using wood as primary cooking fuel (BBS 2022a). One reason may be that crop residue may have become a secondary instead of primary fuel because more households are adopting improved cookstoves (ICSs) with higher fuel efficiency that reduces household demand for crop residue more than for wood. A second reason may be differences in classification of fuels across surveys.

Figure 2.5 Solid fuels used for cooking in Bangladesh, 2011–22 | *Percent of population*



Source: World Bank estimates from (BBS 2015; 2019; 2021; 2022a).

2.3.1 Population exposure to household air pollution

Exposure to household air pollution depends, among other factors, on cooking location and ventilation, type of cooking fuel, and type of cookstove. Three percent of households in Bangladesh cook in the main house with no separate room, 22 percent cook in a separate room in the main house, 42 percent cook in a separate building from the main house, and 33 percent cook outdoors (BBS/UNICEF 2019). Among the solid fuels used by households in Bangladesh, wood tend to be somewhat less polluting than animal dung, grass/shrub, and crop residue (Shupler et al. 2020). Large-scale ICS programs have made inroads in Bangladesh over the last decade. Over 8 percent of households, or nearly 3.5 million, had a stove with a chimney in 2020 (BBS 2021). Most of these stoves are the Bondhu Chula, a fixed-chimney stove with one to three plates, of which 5 million have been distributed.[5] Also, the Infrastructure Development Company Limited (IDCOL) with its partner organizations have sold 3.8 million ICSs as of February 2023.[6] The IDCOL stoves are available in three main types ranging from a portable single-plate stove without chimney to single- and double-plate stoves with chimney. The portable single-plate stove accounts for 88 percent of the number of sold stoves (Berkeley Air Monitoring Group 2022). Combined, the Bondhu Chula and IDCOL programs are distributing about 1 million stoves per year.

Several studies have measured $PM_{2.5}$ in household kitchens in Bangladesh, but few have measured personal $PM_{2.5}$ exposures that are needed to assess health effects of solid-fuel use. One study measured personal $PM_{2.5}$ exposures averaging 144 μg/m³ among 200 adult women cooking with solid fuels in traditional cookstoves (TCS) in rural areas in Chittagong and Dhaka divisions. Measurements were conducted over a 48-hours period once in the dry season and once in the wet season (Shahriar et al. 2021). More recently a study of 300 adult women in five divisions measured personal $PM_{2.5}$ over a 24-hour period in the dry season (Berkeley Air Monitoring Group 2022). Half of the women cooked with solid fuels in TCSs and half with solid fuels in IDCOL's ICSs. Personal exposures averaged 236 μg/m³ among the women cooking with TCS and 179 μg/m³ among the women cooking with ICS.[7]

The personal exposures in those two studies include the exposure to ambient $PM_{2.5}$ in addition to $PM_{2.5}$ from household use of solid fuels. Subtracting ambient $PM_{2.5}$ gives net household air pollution personal exposure among adult women of 77 μg/m³ based the study by Shahriar et al. and 107 μg/m³ based on the study by Berkeley Air Monitoring Group. These estimates are used as low and high personal exposures for the estimation of health effects due to household air pollution from the use of solid fuels. Personal exposures for adult men and children are estimated using women/men and women/children exposure ratios from the Global Burden of Disease (GBD) 2019 that is based on a review of personal exposure studies globally. Thus, average personal exposure for all household members from the use of solid fuels is estimated at 63–88 μg/m³ with a central estimate of 76 μg/m³ (table 2.4). These estimated personal exposures have been adjusted by the share of households with TCS and ICS, and the difference in personal exposure among women using TCS and ICS as found by the Berkeley Air Monitoring Group.[8] The share of households with ICS includes both the Bondhu Chula and IDCOL stoves totaling 8.8 million. Some of these stoves are likely to have been replaced due to old age and damage, or households switching to LPG, gas, or electricity for cooking. The personal exposure estimates are therefore somewhat conservative.

While the ICSs provide only a moderate reduction in exposure to $PM_{2.5}$ household air pollution, the continued expansion of the ICS programs, and the promotion of dual-burner stoves in particular, will continue to be important for households that cannot afford cooking with LPG or electricity and also serve an important role in conserving scarce fuel wood and reduce the use of agricultural residue for cooking. The ICS stoves also reduce $PM_{2.5}$ ambient air pollution because of their improved fuel efficiency and lower $PM_{2.5}$ emissions.

Table 2.4 Estimated personal $PM_{2.5}$ exposure from household air pollution for households using solid fuels in Bangladesh | *μg/m3*

	Women	Men	Children	Average
Low	77	49	66	63
Central	92	59	78	76
High	107	69	91	88

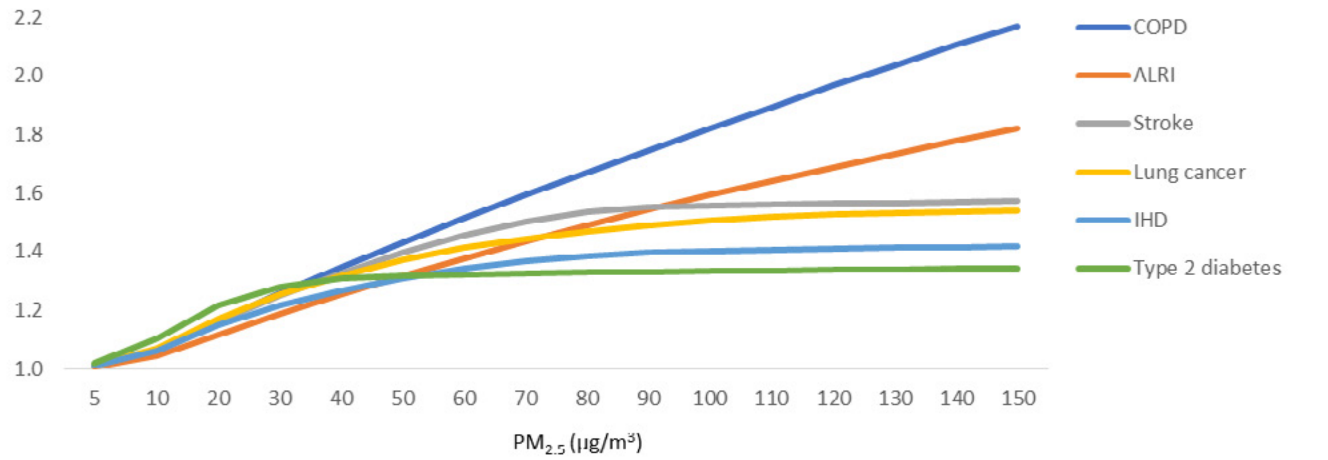
Source: World Bank.
Note: The estimates are net of exposure to ambient $PM_{2.5}$.

2.3.2 Health effects of household air pollution

Health effects of long-term exposure to $PM_{2.5}$ in the household environment from burning of solid fuels include (a) ischemic heart disease (IHD); (b) cerebrovascular disease (stroke); (c) lung cancer (LC); (d) chronic obstructive pulmonary disease (COPD); (e) type 2 diabetes; and (f) acute lower respiratory infections (ALRI), neonatal disorders, and cataract. These are all major health effects evidenced by the GBD 2019 (GBD 2019 Risk Factors Collaborators 2020).

Figure 2.6 shows how the risk of death from the six main health effects increases with increasing levels of $PM_{2.5}$ exposure. The prevalence rates of solid fuel use of 74 percent, the $PM_{2.5}$ exposure levels in table 2.4, and the relative risks of health effects in figure 2.6 are combined to estimate the health effects of household $PM_{2.5}$ air pollution from the use of solid fuels (see methodology in appendix B).

Figure 2.6 Relative risk of mortality from long term $PM_{2.5}$ exposure



Source: GBD 2019 Risk Factors Collaborators (2020) Supplement.
Note: RRs of IHD and stroke are age-weighted.

An estimated 62–74 thousand persons, with a central estimate of 69 thousand, died from $PM_{2.5}$ household air pollution in Bangladesh in 2019. This estimate is based on statistics of baseline deaths in 2019 but population use of solid fuels in 2022 and total distribution of ICSs as of February 2023 by the Bondhu Chula and IDCOL programs to reflect the progress made during the last years on the transition to clean cooking and ICSs. About 59 percent of the deaths from household air pollution were from IHD and stroke; 29 percent from pulmonary diseases (COPD, lung cancer, and ALRI); 5 percent from type 2 diabetes; and 7 percent from neonatal disorders (table 2.5).

Table 2.5 Estimated annual deaths by cause in Bangladesh from $PM_{2.5}$ household air pollution, 2019

	Low	Central	High
IHD	15,807	17,368	18,603
Stroke	21,208	23,262	24,878
COPD	10,441	11,956	13,223
Lung cancer	1,275	1,405	1,505
ALRI	5,828	6,687	7,409
Type 2 diabetes	2,858	3,135	3,354
Neonatal disorders	4,800	5,052	5,305
Total in Bangladesh	**62,215**	**68,866**	**74,278**

Source: World Bank.

Household air pollution also caused an estimated 287–337 thousand DALYs with disease, corresponding to 1.3–1.6 billion days lived with illness. Cataract accounts for the largest share of days lived with illness (41 percent) followed by COPD (21 percent) (table 2.6).[9]

Table 2.6 Estimated days lived with illness from $PM_{2.5}$ household air pollution, 2019 | *Millions*

	Low	Central	High
IHD	199	218	234
Stroke	82	90	96
COPD	268	307	339
Lung cancer	0.46	0.51	0.54
ALRI	13	15	17
Type 2 diabetes	214	235	251
Neonatal disorders	0.69	0.72	0.76
Cataract	561	591	621
Total in Bangladesh	**1,338**	**1,457**	**1,559**

Source: World Bank.

2.3.3 Cost of health effects of household air pollution

The annual cost of health effects of $PM_{2.5}$ household air pollution is estimated at Tk 1,007–1,198 billion in 2019, with a central estimate of Tk 1,112 billion (table 2.7). The cost is equivalent to 3.4–4.1 percent of Bangladesh's GDP that year, with a central estimate of 3.77 percent. Mortality accounts for 79 percent and morbidity for 21 percent of estimated cost (see methodology in appendixes H and I).

Table 2.7 Estimated cost of health effects of $PM_{2.5}$ household air pollution in Bangladesh in 2019 | *Tk, Billions*

	Low	Central	High
Cost of mortality	790	874	943
Cost of morbidity	217	238	255
Total cost of health effects	1,007	1,112	1,198
Percent of 2019 GDP	3.41%	3.77%	4.06%

Source: World Bank.

2.4 Lead pollution

Lead (Pb) exposure continues to be a major environmental health risk in Bangladesh for both children and adults, but the sources of lead exposure are far from fully understood. The population is exposed to lead originating from used lead-acid battery (ULAB) recycling, abandoned ULAB recycling sites, and lead smelting (Ahmad et al. 2014); chemical fertilizers and tanneries (Majumder et al. 2021); jewelry-making industries (Mazumdar, Goswami, and Ali 2017); and electronic waste. Lead exposure also occurs through the use of or contact with articles containing lead such as cookware made of recycled aluminum (ESDO 2018; Weidenhamer et al. 2017), lead-based paint (ESDO/IPEN 2021), cosmetics, toys, as well as through ingestion of other items containing lead. Extremely high concentrations of lead were previously found in turmeric in Bangladesh and a study found evidence of lead additive in turmeric in seven of nine major turmeric producing districts (Forsyth et al. 2019a,b; Gleason et al. 2014). However, the government of Bangladesh implemented measures against this practice, and lead in turmeric was practically eliminated in 2021 (Forsyth et al. 2023).

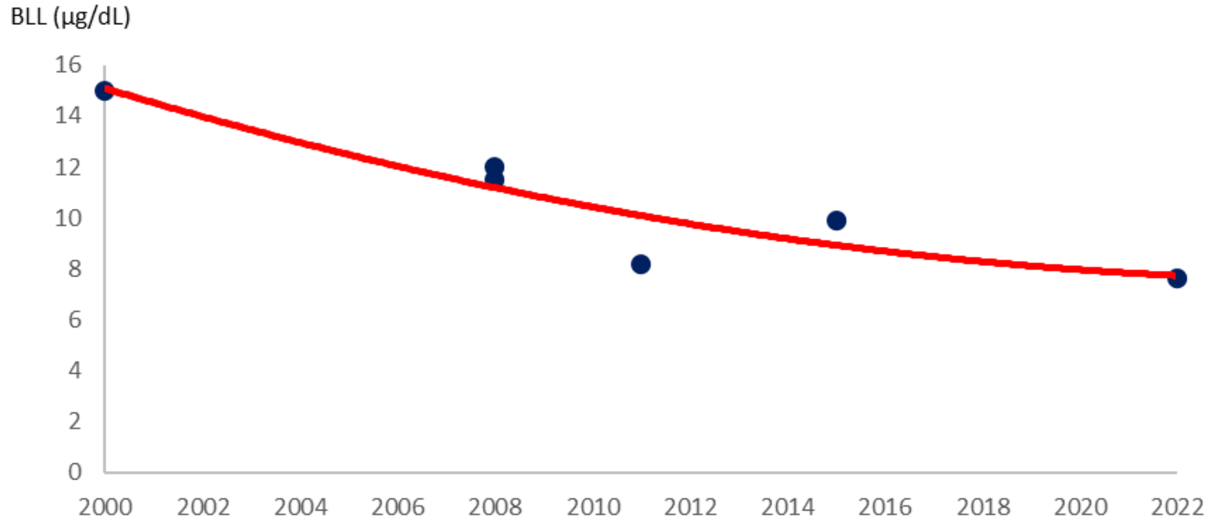
No location is safe from potential lead contamination. Lead pollution in water contaminates fish and other aquatic species and sources of drinking water; lead in soil contaminates agricultural crops and animal fodder; and irrigation water especially from surface water sources contaminates soil and crops. Lead in chemical fertilizers and feed used at fish farms also contributes to the contamination of soil, water, and the food supply. Numerous studies in Bangladesh have documented lead in food and fish (Majumder 2022).

Most recently, Pure Earth conducted a market survey with measurements of lead concentrations in consumer goods and foods in twenty-five countries. The survey found that 44-59 percent of sampled metallic foodware (mostly aluminum), ceramic foodware, and unclassified paints in Bangladesh contained concentrations of lead above references levels, followed by 17 percent for dry staple foods, 13 percent for toys, 9 percent for plastic foodware, and 6 percent for cosmetics (Pure Earth 2023).

2.4.1 Blood lead levels in children and adults

The most common indicator of lead exposure is blood lead level (BLL) measured in units of μg of lead per dL of blood. Estimating health effects of lead exposure in a population requires data on mean BLL in the population and data on the distribution of BLLs around the mean. Current mean BLL in children in Bangladesh is difficult to ascertain in the absence of up-to-date BLL measurement studies representative of the wider population of children in the country. Six studies of children's BLLs in Dhaka are presented in figure 2.7. These studies are the ones that best reflect the general BLL of the children in the city and metropolitan area since the banning of lead in gasoline in Bangladesh in 1999. Mean BLL declined from 15 μg/dL in 2000 to 7.6 μg/dL in 2022.

Figure 2.7 Trend in children's mean blood lead level in Dhaka, 2000–22 | *μg/dL*



Sources: icddr,b 2022; Kaiser et al. 2001; Linderholm et al. 2011; Raihan et al. 2018; Wasserman et al. 2011; 2018.

Four additional studies shed light on children's BLLs in rural and peri-urban Bangladesh. These studies date back to 2007 to 2013 and found mean BLLs from 2.5 to 9.1 μg/dL in the Dhaka, Rajshahi, and Rangpur Divisions (Gleason et al. 2020; Mitra et al. 2009; Mitra et al. 2012; Woo et al. 2018). Average BLL across these four studies was 5.85 μg/dL. A study by IEDCR in 2022 of 980 children under 18 years of age in four districts across Bangladesh found an average BLL of 5.63 μg/dL. Among the children under five years of age, the average BLL was 7.4 μg/dL among those living within the reach of ULAB recycling activities and 4.5 μg/dL among those living in areas without such activities (see appendix C).

The studies from Dhaka and rural and peri-urban areas indicate a central estimate of nationwide mean BLL in children of 6.4 μg/dL within a range from 5.7 to 7.0 μg/dL in 2022 (table 2.8). The range in urban and rural areas is determined by assumptions about the rate of decline in BLLs over the last decade. The "low" case is based on the linear trend of BLLs in urban areas and a moderate reduction in BLLs in rural areas. The "high" case is based on the assumption of minimal decline in BLLs over the last decade.

Table 2.8 Estimated mean BLLs in children in Bangladesh, 2022 | *μg/dL*

	Low	Central	High
Urban	7.0	8.0	9.1
Rural	5.0	5.4	5.9
National	5.7	6.4	7.0

Source: World Bank.

Very few recent and relevant studies of BLLs were identified for adults during the preparation of this report. Two studies of pregnant women with a mean age of 23–24 years in three rural locations indicate an average BLL of 4.9 μg/dL (Forsyth et al. 2018; Gleason et al. 2020). One study in two rural locations found average BLL of 7.7 μg/dL (Bulka et al. 2019). However, the studies are 10–15 years old. Overall, it may be expected that average BLL in adults 25+ years of age may be as high as among children under five, given that older adults have higher BLL than young children, and young adults generally have a lower BLL than young children. Therefore, the "low", "central", and "high" national means for children are applied to adults for the purpose of estimating the health effects of lead exposure.

The BLL measurement studies of children and adults discussed above largely reflect populations living in areas with no obvious major source of lead exposure. However, there are many "hot spots" with children and adults having substantially higher BLLs.

Informal recycling of ULABs, including abandoned recycling sites, are major lead-exposure "hot spots" in Bangladesh and many other low- and middle-income countries for workers and nearby residents (Ericson et al. 2016; Gottesfeld and Pokhrel 2011). The Toxic Sites Identification Program (TSIP) implemented by Pure Earth has since 2011 in partnership with the Department of

Geology of the University of Dhaka and the Department of Environment of Bangladesh assessed 249 contaminated sites. 175 of the sites are ULAB recycling and lead smelting sites located throughout the country (McCartor 2018). The total number of ULAB recycling and recharging facilities are, however, substantially larger, reported in the range of 1,100 (World Bank 2018) to 12,200 (Ahmad et al. 2014). The latter figure is based on a survey dating back to 2003–04 by the Bangladesh Bureau of Statistics (BBS).

A study of workers at 15 ULAB recycling and recharging facilities in Dhaka City found a mean BLL of 65 μg/dL (Ahmad et al. 2014). A study at an abandoned ULAB-recycling site in Kathgora, Savar in Dhaka Division measured BLLs of children living within 200 meters of the site. The site had been in operation for six months before it was closed. Children's median BLLs were 23 μg/dL about two years after the site was abandoned. After an exposure risk reduction intervention median BLLs dropped to 15 μg/dL. The intervention involved community education, soil remediation, and cleaning of households to remove lead-contaminated dust (Chowdhury et al. 2021; McCartor and Nash 2018). A study of jewelry makers of 32–62 years of age in Dhaka in 2015 found an average BLL as high as 69 μg/dL. BLLs among background office staff were also elevated with an average BLL of 16 μg/dL (Mazumdar, Goswami, and Ali 2017).

A log-normal distribution of BLL of the population in Bangladesh (Fewtrell, Kaufmann, and Prüss-Üstün 2003) indicates that 57 percent of children under five years of age, 61 percent of adult males, and 51 percent of adult females have a BLL ≥ 5 μg/dL, and over one-third of the population has a BLL > 10 μg/dL (table 2.9). These estimates include the populations in lead exposure "hot spots". The difference in the adult male and female BLL distributions reflects that adult males generally have substantially higher BLLs than adult females (Bulka et al. 2019).

Table 2.9 Estimated population blood lead level (BLL) distribution in Bangladesh, 2022

BLL (μg/dL)	Percent of children (< 5 years)	Percent of male adults (25+ years)	Percent of female adults (25+ years)
< 2.0	20	18	25
2.01–5.0	23	21	24
5.01–10.0	20	19	19
> 10	37	42	32

Source: World Bank.
Note: Mean BLL = 6.4 μg/dL and standard deviation (SD) = 4.02 for children; mean BLL = 7.5 μg/dL and SD = 4.27 for adult males; and mean BLL = 5.27 μg/dL and SD = 4.04 for adult females.[10]

2.4.2 Lead exposure from soil, dust, and drinking water

The World Bank commissioned a study to review available evidence from research in Bangladesh on major sources of lead pollution; lead concentrations in soil/dust, air, drinking water, and foods; and population exposure to the pollution (Majumder 2022). The study drew on nearly one hundred research studies and articles and conducted several focus group discussions with a total of 61 participants from government departments, various institutions and universities, and the media.

Twenty-two studies of lead concentrations in soil and dust in Bangladesh are summarized in Majumder et al. (2021). Average lead concentrations in agricultural soils, garden soils and roadside soils and dust were 75 mg/kg (ppm). Lead concentrations are substantially higher in many industrial and mining areas and ULAB sites but affect a relatively minor share of the population in Bangladesh. Lead in air was a major source of lead ingestion during the times of leaded gasoline. Mean lead concentrations in air were 0.36 $\mu g/m^3$ in the studies reviewed by Majumder et al. (2021) that best reflect the exposure of the general population. Lead exposure also comes from drinking water. Well over 95 percent of the population in Bangladesh rely on groundwater (Shamsudduha et al. 2019). A review of available studies reports lead concentrations in groundwater of 1 μg/L or less in most locations (Hasan, Shahriar, and Jim 2019; Parvin, Haque, and Tareq 2021). This concentration is well below WHO's guideline value of 10 μg/L (see appendix C).

Table 2.10 presents mean lead concentrations in soil, air, and drinking water to which the general population appear to be exposed. These concentrations are estimated to result in a BLL of 1.9 μg/dL in two-year-old children. This magnitude of effect on BLL represents about 30 percent of mean BLLs of children under five years of age in Bangladesh. Soil alone contributes an estimated 1.6 μg/dL.[11] The effect on BLL is higher for younger children compared to older children.

Table 2.10 Mean lead concentrations in soil, air, and drinking water and modeled BLLs in children

	General population
Soil	75 mg/kg
Air	0.36 μg/m^3
Drinking water	1 μg/L
Estimated effect on BLL	1.9 μg/dL

Source: World Bank estimates using the IEUBK Model Version 2.
Note: Effect on BLL is for children two years of age.

2.4.3 Lead exposure from food

Heavy metal contamination of food for human consumption is receiving increased attention. Collado-López et al. (2022) reviewed 152 studies in 43 countries worldwide. Vegetables, fish, and rice were the most studied food groups and over half of the studies were from Asia. Food may be a major source of lead exposure in Bangladesh possibly for a large share of the population. This section presents lead concentrations in rice, vegetables and fish in Bangladesh as reported by three review studies (Islam et al. 2018a; Kumar et al. 2022; Majumder et al. 2021) and several individual studies (see appendix C). These three food groups constitute nearly 80 percent of the daily quantity of food consumption in Bangladesh with rice alone accounting for nearly half of daily food weight intake.

Rice: A wide range of lead concentrations have been detected in rice in Bangladesh in the studies reviewed by Kumar et al. (2022). The studies showed a mean concentration of 2.23 mg/kg of rice, largely driven by very high concentrations in a small subset of the studies. Two other studies found substantially lower lead concentrations: Jahiruddin et al. (2017) found mean concentrations of 0.20 mg/kg in four subdistricts (upazilas) in the Dhaka and Mymensingh Divisions. Real, Azam, and Majed (2017) sampled ten rice varieties from Kawran Bazar, the largest wholesale market in Dhaka, and found lead concentrations of 0.0–0.08 mg/kg. No study of lead in rice in Bangladesh is nationally representative. The mean nationwide lead concentration is therefore highly uncertain but may be in the range of 0.1–0.2 mg/kg and possibly lower or higher.

Vegetables: Vegetables are the second most important source of food in terms of daily intake weight. Several reviews and additional individual studies indicate that mean lead concentrations are in the range of 0.43–1.03 mg/kg in commonly consumed vegetables (Bushra et al. 2022; Haque et al. 2021; Islam et al. 2018a; Kumar et al. 2022; Majumder et al. 2021; Sultana et al. 2022). Two of the studies are measurements from large wholesale vegetable markets. However, two additional studies from wholesale markets show mean lead concentrations of less than 0.06 mg/kg (Real, Azam, and Majed 2017; Shaheen et al. 2016), indicating that larger samples over longer periods of time covering both the rainy and dry seasons may be required to provide more accurate perspectives on lead concentrations in vegetables nationally.

One potential source of widespread lead in rice and vegetables may be chemical fertilizers. Mohiuddin et al. (2017) measured lead in 54 fertilizer samples from the markets of four districts of Bangladesh. Mean lead concentrations in various types of fertilizers were 100–400 mg/kg.

Fish: Fish is the third most important food group in Bangladesh in terms of per capita quantity of consumption and the most important source of protein. Bangladesh ranked third in the world in inland capture fisheries and fifth in culture fisheries production in 2019 (GoB 2020) and fishery production has increased nearly six-fold from 1985 to 2019. Inland culture fisheries experienced the highest growth rate at 9.2 percent per year, followed by marine fisheries at 3.8 percent per year and inland capture fisheries at 2.9 percent per year. Islam et al. (2018a) and Majumder et al. (2021) reviewed seven studies of lead concentrations in fish from six rivers. Mean concentrations ranged from 0.04 to 9.97 mg/kg. Majumder (2022) presents studies of lead in cultured fish. Mean lead concentrations were 0.64 mg/kg in the five studies with lowest concentrations and 8.9 mg/kg in the two studies with highest concentrations. Two studies of lead in fish from the Kawran Bazar fish market in Dhaka found very divergent concentrations. Real, Azam, and Majed (2017) reported concentrations of 0.04–1.04 mg/kg while Shovon et al. (2017) reported a mean of 7.1 mg/kg in three common fish species.

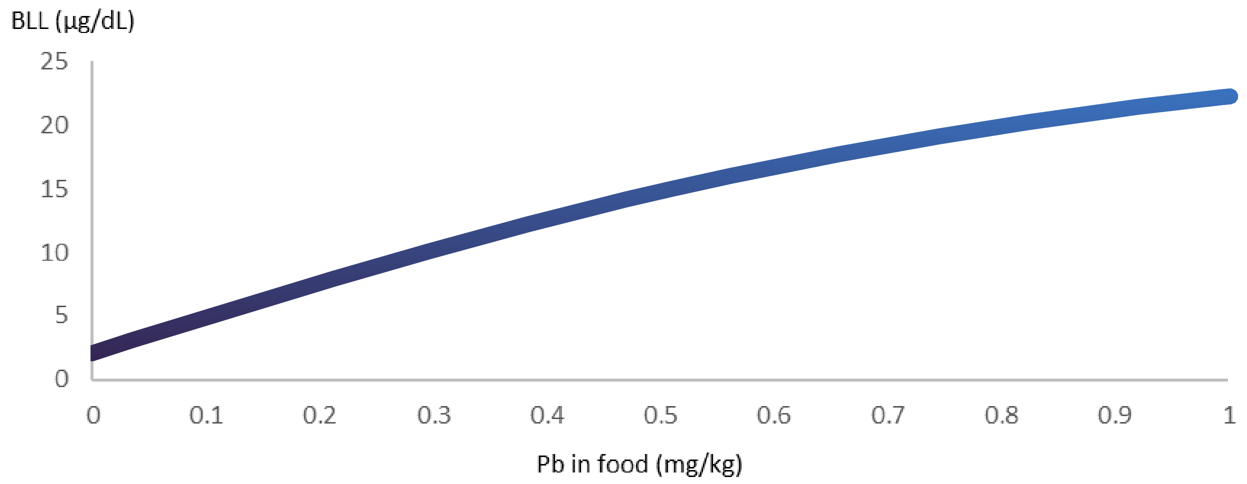
Studies have also found high concentrations of lead in commercial feed used at fish farms with mean concentrations ranging from 6 to 10 mg/kg. These lead concentrations in feed were highly correlated with lead concentrations in farmed fish (Kundu et al. 2017; Saha, Mottalib, and Al-Razee 2021).

The studies with the lower mean lead concentrations in fish may best reflect nationwide population exposure to lead in fish, while the studies with the higher mean concentrations may indicate exposure levels for a relatively small share of the population. This suggests that nationwide population exposure to lead in fish could be somewhere in the range of 0.04–0.74 mg/kg for captured fish and 0.13–1.6 mg/kg for cultured fish. To calculate daily intake of lead per person from fish consumption, lead concentrations in fish reported in mg/kg dry weight must be converted to fresh weight by multiplying by a factor of 0.208 (Saha, Mottalib, and Al-Razee 2021).

Predicted BLL from lead in food: The studies of lead concentrations in food in Bangladesh raise serious concerns about food safety and public health. The Integrated Exposure Uptake Biokinetic (IEUBK) Model Version 2 is applied to predict the effect on BLL of a two-year old child from ingestion of lead in food. Daily dietary intake of lead is determined by daily quantity of food ingested, lead concentrations in food ingested, and potential losses of lead from cooking. A two-year-old child is assumed to consume 300 grams of food per day, compared to about 800 grams for an adult in Bangladesh. BLL is modelled for 0.01–1.0 mg/kg of lead concentrations in food to understand how BLLs of different segments of the population may be affected by lead in food. Losses of lead from cooking is set at 33 percent according to the rate found by Islam et al. (2022) for rice in Bangladesh. Losses may stem from evaporation or from the leaching of lead from solid foods into cooking liquids that are not consumed.

A lead concentration of 0.15 mg/kg in food ingested by a two-year-old child is predicted to cause a BLL of 6.6 µg/dL including 1.9 µg/dL from other sources (that is, soil and dust, air, water). This BLL is slightly above the estimated average BLL of children under five years in Bangladesh (figure 2.8). This is a plausible average concentration of lead in food for a large share of the population. In this case, lead in food may be responsible for as much 70 percent of average BLL while lead from soil/dust, air and drinking water contributes the remaining 30 percent. At a lead concentration of 0.05 mg/kg in food, BLL is predicted at 3.6 µg/dL of which 1.7 µg/dL from food and 1.9 µg/dL from soil, air and drinking water. In this case, 45 percent of the average BLL of 6.4 µg/dL in children is due to sources other than food, soil/dust, air, and drinking water, which could be lead in recycled aluminum cookware, toys, paint, and other articles. At a lead concentration of 1.0 mg/kg in food, BLL is predicted at 23 µg/dL of which 21 µg/dL is from food.

Figure 2.1 Predicted BLL from Pb in food for a two-year-old child



Source: World Bank based on application of the IEUBK Model Version 2.

An additional effect of lead in agricultural soils is the absorption of lead in rice straw. Lead concentrations in rice straw has been found to be 5–6 times higher than in rice grain (Kibria 2012). Using rice straw, as well as other agricultural residues with lead accumulation, for household energy may therefore cause lead air pollution, an issue that needs investigation.

2.4.4 Lead exposure from cookware

Aluminum cookware can also be a source of lead exposure as evidenced from multiple studies in Asia and Africa (Mathee and Street 2020). Toxic metals are often released into food during cooking especially from cookware made from recycled aluminum. Metals include lead, arsenic, mercury, cadmium, copper, and aluminum. Most of the studies are from Africa (Jitaru et al. 2019; Street et al. 2020; Weidenhamer et al. 2014; Weidenhamer, Chasant, and Gottesfeld 2022), but studies of cookware have also been undertaken in Bangladesh and several other Asian countries including India, Indonesia, Nepal, the Philippines, and Vietnam (Weidenhamer et al. 2017).

Studies show a very large range of lead released during cooking. Many cookware items were found not to release detectable levels of lead while others released lead up to 260 μg per 250 mL food serving (Weidenhamer, Chasant, and Gottesfeld 2022; Weidenhamer et al. 2014; 2017). The magnitude of lead released from cookware also seems to vary by type of food being cooked (Jitaru et al. 2019).

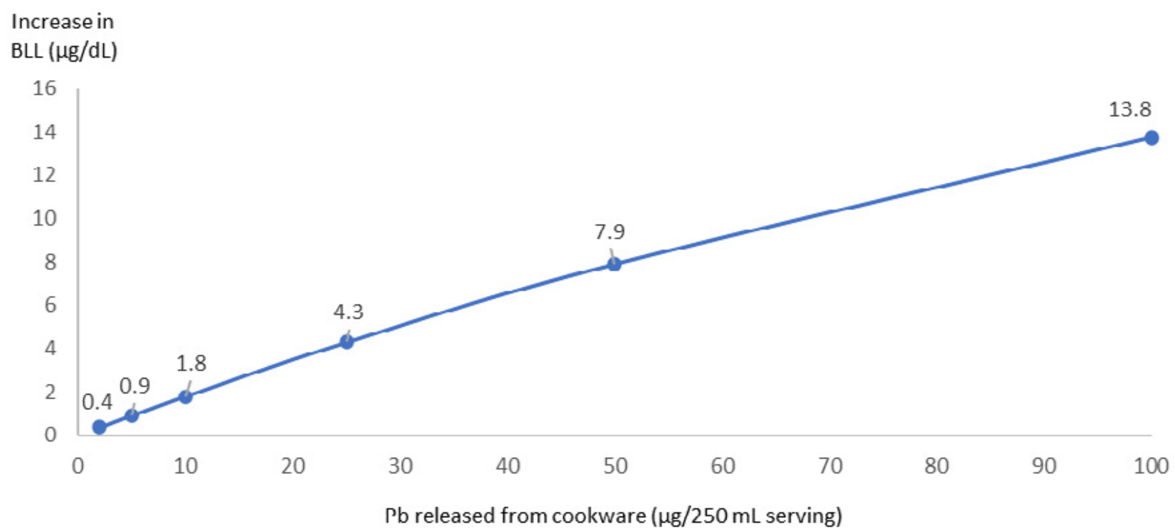
A study evaluated the protection against lead released to food from fluoropolymer coatings of four cookware items. The reduction in the release of lead ranged from 42 to 100 percent, while average reduction in aluminum was 98 percent and the release of cadmium was reduced to nondetectable levels (Weidenhamer et al. 2017).

Most of the population in Bangladesh prepares food with aluminum cookware since it is inexpensive, easy to handle because of its light weight, and heats the food faster than many alternative cookware (ESDO 2018). Four recycled aluminum cookware items were tested in Bangladesh in the study reported by Weidenhamer et al. 2017. One of the four items released 2 μg of Pb per 250 mL serving while no detectable lead was released from the other three items. All four items released arsenic and aluminum, and one item released cadmium. The market survey by Pure Earth sampled 27 items of metallic cookware in Bangladesh of which 59 percent had Pb concentrations above the reference level of 100 ppm, with a median and maximum Pb concentration of 186 and 8,186 ppm, respectively (Pure Earth 2023). The items have not been tested for leaching of Pb into food while cooking.

The IEUBK Model Version 2 is applied to predict the effect on BLL of a two-year-old child from ingestion of lead in food leached from aluminum cookware. If 2 μg of Pb per 250 mL serving is regularly released from aluminum cookware, as found for one of the four aluminum cookware items in Bangladesh, the effect on the child's BLL is predicted to be an increase of 0.4 μg/dL.[12] This is 6 percent of the estimated average BLL in children under five years of age in Bangladesh. However, some aluminum cookware items may release far more lead, as found in several countries in Africa and Asia. The predicted increase in BLL is as high as 13.8 μg/dL if 100 μg of Pb per 250 mL serving is released (figure 2.9).

Most of the cookware is made locally in Bangladesh, but little information is available on the fraction of aluminum cookware made from recycled metal. More studies of the sources of aluminum used for cookware production and the magnitude of leaching of lead and other toxic metals during cooking are much needed in Bangladesh.

Figure 2.8 Predicted increase in BLL from Pb in aluminum cookware for a two-year-old child

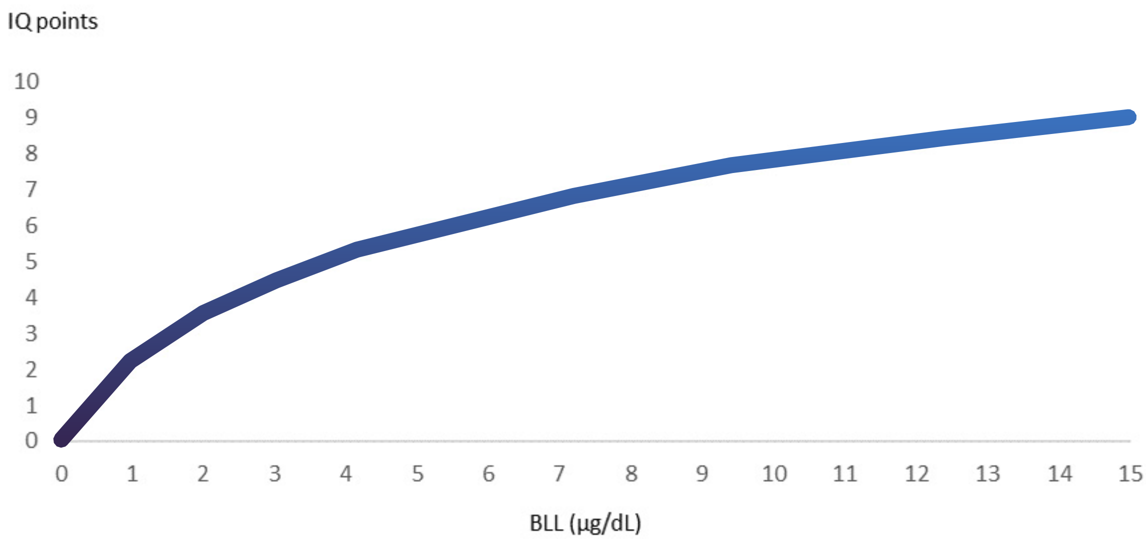


Source: World Bank based on application of the IEUBK Model Version 2.

2.4.5 Health effects of lead exposure on children

Effects of lead exposure in children include cognitive impairment, increased risk of attention deficit or hyperactivity disorder, and increased risk of antisocial and criminal behaviors (Landrigan et al. 2018). One such well-established and quantifiable effect of lead exposure in children is neuropsychological impairment measured as IQ loss.[13] A seminal study by Lanphear et al. (2005), based on a pooling of seven international longitudinal cohort studies, specified a log-linear function that best describes the relationship between children's BLL and their IQ. A subsequent study, also using the same pooled data, took the analysis further (Crump et al. 2013) and is used here to estimate annual losses of IQ points among children under five years of age in Bangladesh (figure 2.10).[14] Since no safe BLL has been established, a theoretical minimum-risk exposure level (TMREL) of 0 µg/dL is applied here to estimate IQ losses (see appendix D).

Figure 2.11 Loss of IQ points from lead exposure in early childhood



Source: World Bank, produced from the log-linear function reported in Crump et al. (2013).

Total annual losses of IQ points among children under five years of age are estimated at 18.9–20.4 million with a central estimate of 19.7 million based on the average BLLs in children in the range of 5.7–7.0 µg/dL discussed in this section (table 2.11).[15] The central estimate corresponds to an average of nearly 7 IQ points per child over the child's early years of life. About 58 percent of the annual losses are among children with a BLL greater than 10 µg/dL while less than 7 percent of annual losses are among children with a BLL less than 2 µg/dL.[16]

Table 2.11 Estimated annual losses of IQ points among children < 5 years in Bangladesh, 2019 | *IQ points, millions*

BLL (µg/dL)	Lower	Central	Upper
< 2	1.44	1.31	1.20
2.0–5.0	3.23	3.10	3.01
5.01–10.0	3.82	3.84	3.86
> 10	10.41	11.49	12.31
Total in Bangladesh	**18.90**	**19.74**	**20.39**

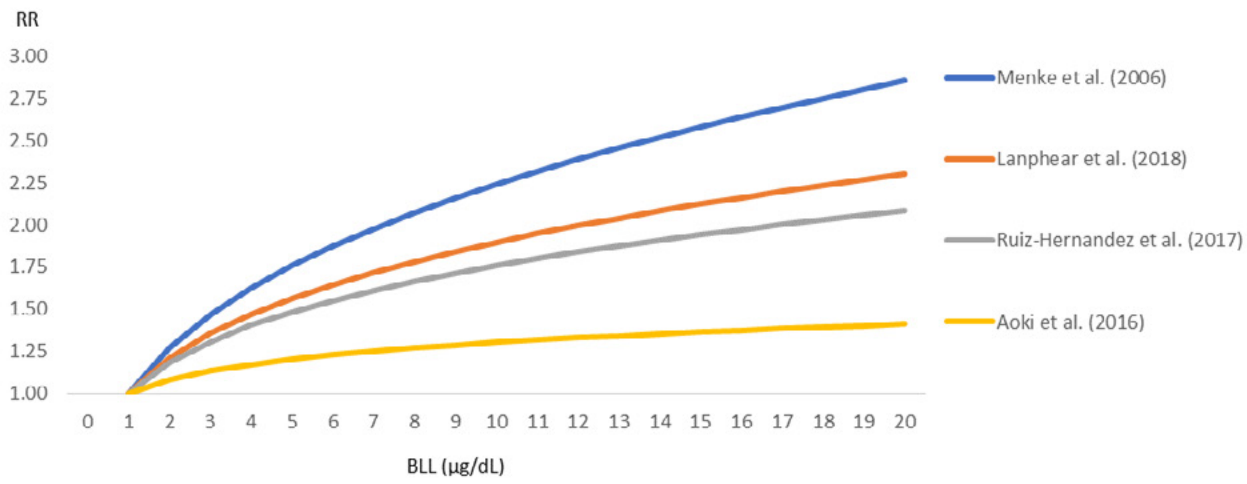
Source: World Bank.

2.4.6 Health effects of lead exposure in adults

The GBD 2019 estimated that there were 30,800 deaths from lead exposure in Bangladesh in 2019, of which 29,900 were cardiovascular disease (CVD) deaths and 900 were chronic kidney disease (CKD) deaths (GBD 2019 Risk Factors Collaborators 2020). The methodology used by the GBD 2019 may, however, only capture a portion of CVD deaths from lead exposure because the GBD estimated CVD mortality only through the effect of lead on blood pressure, and of blood pressure on CVD mortality. Lead exposure has, however, cardiovascular effects beyond effects mediated through blood pressure (Lamas et al. 2023; Larsen and Sánchez-Triana 2023; Shaffer et al. 2019). An alternative approach to estimating global CVD mortality from lead exposure is therefore to rely on research that directly estimates CVD mortality rather than through blood pressure as suggested by Shaffer et al.

Brown et al. (2020) developed a health-impact model that used the concentration-response relationship between BLLs and CVD mortality risk from four studies, thus directly estimating CVD mortality (Aoki et al. 2016; Lanphear et al. 2018; Menke et al. 2006; Ruiz-Hernandez et al. 2017). All four studies analyzed BLLs of the adult population in the United States from one or more of the nationally representative National Health and Nutrition Examination Surveys (NHANES) from 1988 to 2010 (CDC 2023). The studies found a wide range in relative risk (RR) of CVD mortality. At the estimated average BLL of 6.4 μg/dL in Bangladesh the increased risk of CVD mortality is 24–91 percent higher than in absence of lead exposure (figure 2.11). This implies an estimated 61,800 CVD deaths from lead exposure in 2019 based on Aoki et al. and as high as 160,000 deaths based on Menke et al. This is more than 2–5 times higher than the GBD 2019 estimate. Using the midpoint of Lanphear et al. and Ruiz-Hernandez et al., as in Larsen and Sanchez-Triana (2023), estimated CVD deaths from lead exposure were 97,100 deaths in 2019.

Figure 2.21 Relative risk of CVD mortality from BLL of 1–20 | *μg/dL*



Source: World Bank, derived from Brown et al. (2020) and the four studies noted in the figure. See appendix E.

To conservatively estimate the cost of lead exposure in adults, the estimate of CVD mortality based on Aoki et al. is used as the base case. This implies that CVD deaths were about 59–64 thousand in 2019 with a central estimate of 61,800 based on average adult BLLs in the range of 5.7–7.0 μg/dL. Lead exposure also caused an estimated 403–431 million days lived with cardiovascular illness (table 2.12).[17] The estimated CVD deaths from adult lead exposure is based on a TMREL BLL of 0 μg/dL. Applying instead a TMREL of 1 μg/dL, as suggested by the relative risk functions in figure 2.11, reduces estimated annual CVD deaths only marginally from 61,800 to 61,000.

Table 2.12 Estimated annual deaths and illness from lead exposure among adults in Bangladesh, 2019

	Low	Central	High
Cardiovascular disease deaths	59,452	61,800	63,565
Days lived with cardiovascular illness (millions)	403	419	431

Source: World Bank.

2.4.7 Cost of health effects of lead exposure

Cost of IQ losses

The cost of IQ losses is estimated by the effect of IQ on lifetime income. The relationship between IQ and lifetime income has long been established (Grosse and Zhou 2021; Johnson and Neal 1998; Lin, Lutter, and Ruhm 2018; Lundborg, Nystedt, and Rooth 2014; Salkever 1995; 2014a,b; Schwartz 1994; USEPA 2020; Zax and Rees 2002). Multiple studies have used this relationship for estimating the cost of IQ losses from lead exposure in France, the United States, and in low- and middle-income countries (Attina and Trasande 2013; Gould 2009; Grosse et al. 2002; Muennig 2009; Pichery et al. 2011).

The present value of future lifetime income of a child under five years is estimated at Tk 4.2 million. This is based on an estimated average annual labor income in Bangladesh in 2019 of Tk 219,682.[18] The cost of a lost IQ point is estimated at Tk 52.1 thousand, based on the estimate of 2.0 percent lifetime income loss per IQ point (see appendix G). This is estimated as the loss of income per lost IQ point multiplied by the percentage of children that may be expected to participate in the labor force. Expected labor force participation is assumed to be the same as the current rate of participation. With an estimated annual loss of 18.9–20.4 million IQ points among children under five in Bangladesh, the estimated annual cost is Tk 985–1,063 billion in 2019, with a central estimate of Tk 1,029 billion. This is equivalent to 3.3–3.6 percent of Bangladesh's GDP that year, with a central estimate of 3.5 percent of GDP (table 2.13).

Table 2.13 Estimated annual cost of IQ losses among children under five years of age in Bangladesh, 2019

	Low	Central	High
Present value of future lifetime income (18–65 years) (Tk)	4,202,088	4,202,088	4,202,088
Lifetime income loss per IQ point lost (percent of lifetime income)	2.0%	2.0%	2.0%
Labor force participation rate (18–65 years)	62%	62%	62%
Cost per lost IQ point (Tk)	52,106	52,106	52,106
IQ points lost per year (millions)	18.90	19.74	20.39
Total cost (Tk, billions)	985	1,029	1,063
Percent of 2019 GDP	3.34	3.49	3.60

Source: World Bank.

Cost of adult health effects

Among adults, an estimated 59–64 thousand individuals died prematurely, and 403–431 million days of illness occurred from nonfatal cardiovascular disease due to lead exposure in 2019. The annual cost of these health effects is estimated at Tk 800–855 billion, with a central estimate of Tk 832 billion (table 2.14).

Table 2.14 Estimated annual cost of health effects of adult lead exposure in Bangladesh, 2019 | *Tk, billions*

	Low	Central	High
Cost of mortality	755	784	807
Cost of morbidity	45	47	48
Total cost of health effects	800	832	855
Percent of 2019 GDP	2.71	2.82	2.90

Source: World Bank.

The cost is equivalent to 2.7–2.9 percent of Bangladesh's GDP in 2019, with a central estimate of 2.8 percent. Mortality accounts for 95 percent and morbidity for 5 percent of estimated cost (see appendixes H and I). The total estimated cost of lead exposure—that is, the effects of lead on children and adults—is Tk 1,785–1,918 billion in 2019 with a central estimate of Tk 1,860 billion. This is equivalent to 6.0–6.5 percent of GDP that year, with central estimate of 6.3 percent of GDP.

2.5 Household drinking water, sanitation, and hygiene

Water resources are of immense importance to Bangladesh, not only for municipal and household water supply, but also for fisheries, irrigation and agriculture, and industry. However, heavy metals and chemical pollution is affecting these resources as well as agricultural soils and crop production. Uddin and Jeong (2021) found high levels of heavy metal pollution in multiple rivers. Islam et al. (2018c) identified cadmium, arsenic, chromium, copper, lead, and nickel as priority pollutants for control, with high concentrations of many of these pollutants in irrigation water and agricultural soils exceeding FAO guidelines. Islam et al. (2018a) undertook a review of the literature on arsenic, lead, cadmium, and chromium pollution of waters, soils, and foods in Bangladesh and concluded that contamination from geological, industrial waste, and urban sources is a major issue that needs further assessment.

Industrial and agrochemical pollution are two major sources of water pollution. This includes heavy metals and chemical pollution of water resources that poses a health threat through the food supply. The pollution impacts both captured and cultured fish. It also impacts agricultural crops through irrigation on top of other sources of agricultural soil pollution. This is assessed in section 2.4 for lead pollution based on published data and research while comprehensive health risk assessments are yet to be undertaken for other heavy metals and chemicals. Heavy metals and chemical pollution may also affect drinking water supplies. Drinking water to date does not seem to suffer from lead pollution (section 2.4.2). Arsenic contamination is discussed below in section 2.5.2. Salinity intrusion is also an environmental health concern especially in coastal districts where it is affecting the quality of drinking water supply, agriculture productivity, and public health.

Rising water stress and declining groundwater levels in some of the dense settlements in Bangladesh combined with these pollution issues can lead to substantial negative impacts on access to safe and clean drinking water, crop production, and broader public health outcomes. These challenges are compounded by climate change impacts in terms of availability of safe water, floods, and saline intrusion. Inadequate fecal sludge management is another issue that affects water quality and public health.

Many of these water-resources issues are discussed in Joseph and Shrestha (2021) while this report focuses exclusively on household drinking water, sanitation, and hygiene. The health effects of inadequate WASH assessed in this report arise from two principal sources: (a) fecal contamination or microbiological pollution in relation to drinking water, sanitation, and hygiene; and (b) exposure to arsenic in groundwater tubewells used for drinking.

2.5.1 Microbiological pollution

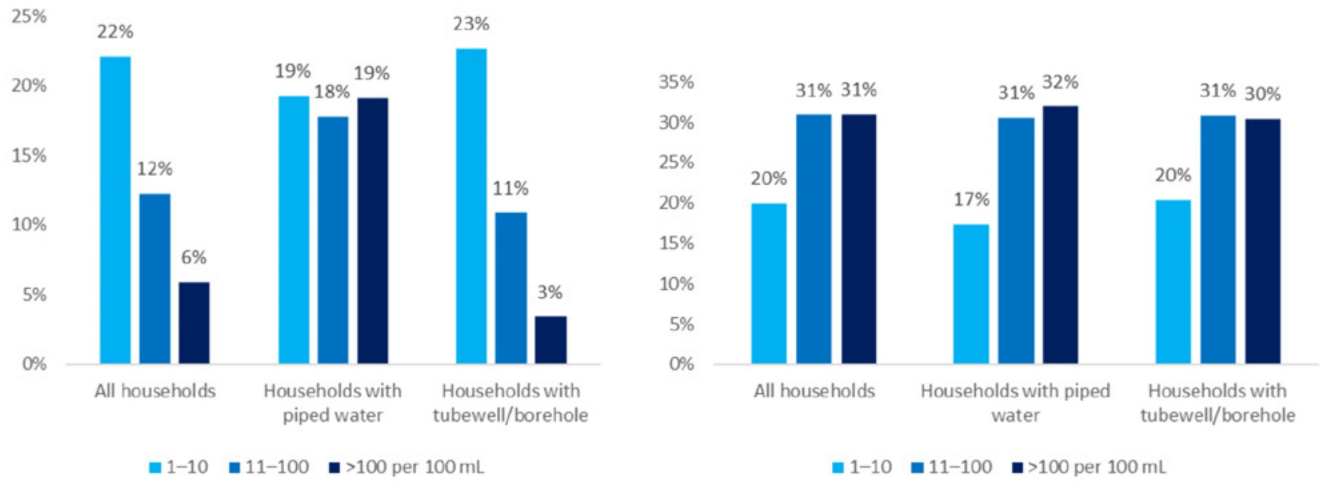
The health safety of drinking water is influenced not only by the type of water supply but also by drinking-water accessibility, availability when needed, quality of water at source, household collection, storage, and point-of-use treatment practices before drinking. Therefore, WHO/UNICEF reports an indicator called "safely managed drinking-water services" defined as an improved drinking-water source that is free from microbiological (E. coli) and priority chemical contamination (arsenic and fluoride), is located on premises, and is available when needed (UNICEF/WHO 2019).

An estimated 99 percent of the population in Bangladesh used an improved water source for drinking in 2019 according to the nationally representative Bangladesh Multiple Indicator Cluster Survey (MICS) 2019 (BBS/UNICEF 2019). Not all of these water sources meet the WHO/UNICEF criteria for safely managed drinking water.

Over 82 percent of the population of Bangladesh had their drinking-water source on premises in 2019. However, nearly 17 percent of households spent from 30 to 60 minutes per day collecting water, and over 6 percent of households spent more than one hour per day collecting water according to the MICS survey.

The MICS survey also included testing for E. coli bacteria—an indicator of fecal contamination—in the source water and in actual drinking water of over 6,000 households throughout Bangladesh. 40 percent of the household population had E. coli in their source water and as many as 82 percent had E. coli in their actual drinking water, suggesting a high incidence of contamination from the point of drinking-water collection to drinking-water storage. The presence of E. coli in source water was substantially higher among households with piped water supply than among households with tubewell/borehole (figure 2.12, left). In the actual drinking water at point of household storage, the presence of E. coli in water from piped sources and tubewell/boreholes was very similar (figure 2.12, right).

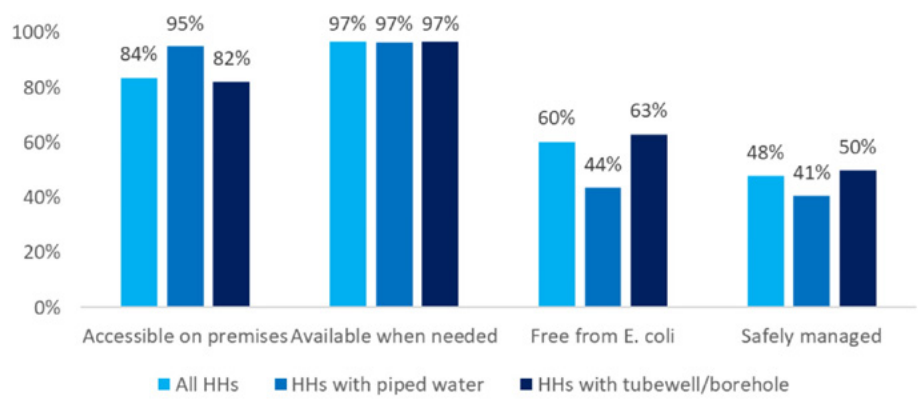
Figure 2.12 Population with E. coli in source water (left) and actual drinking water (right), 2019



Source: World Bank, produced from BBS/UNICEF (2019).
Note: Number of E. coli per 100 ml of water.

Only 48 percent of the population in Bangladesh had safely managed drinking water in 2019, ranging from 41 percent among households with piped water supply to 50 percent among households with tubewell/borehole (figure 2.13). Safely managed water is based on source water of which 60 percent is free from E. coli. However, as discussed, only 18 percent of actual drinking water was free from E. coli. The difference between the percentage of population with source water free from E. coli and actual drinking water free from E. coli points to the importance of safe handling and storage of drinking water, as well as the need to improve quality of piped water supply. It also highlights the role of household point-of-use treatment of drinking water in ensuring drinking water that is free from microbiological pollution.

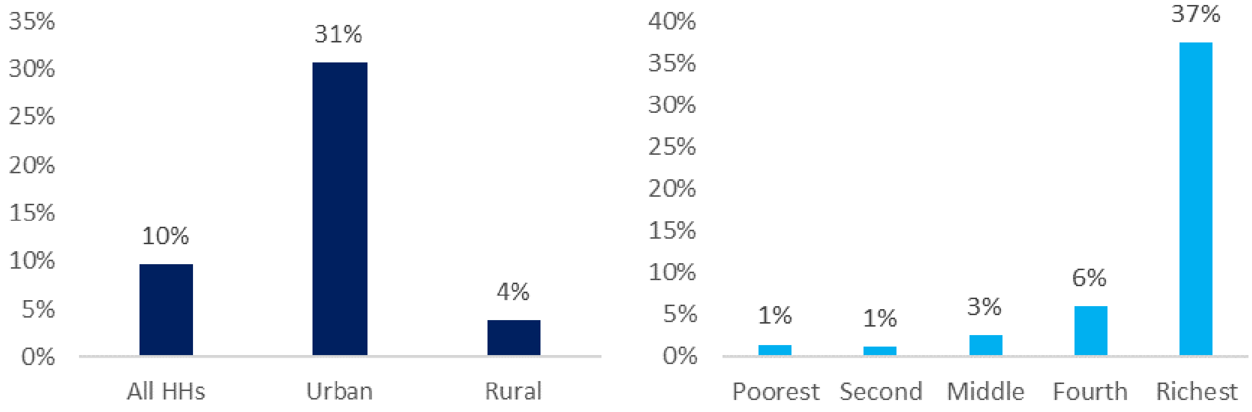
Figure 2.13 Population with safely managed drinking water, 2019



Source: World Bank, produced from BBS/UNICEF (2019).
Note: HHs = households.

Only about 10 percent of the household population in Bangladesh reported that they treated their water prior to drinking in 2019 by an appropriate method.[19] The main method of treatment was boiling (5 percent) and filtering of water (6 percent). The prevalence of drinking-water treatment is particularly low in rural areas. By household living standard, the drinking-water treatment rate is 37 percent among the richest quintile of households versus 1 percent among the two poorest quintiles (figure 2.14).

Figure 2.14 Household treatment of drinking water, 2019 | *Percent of population*



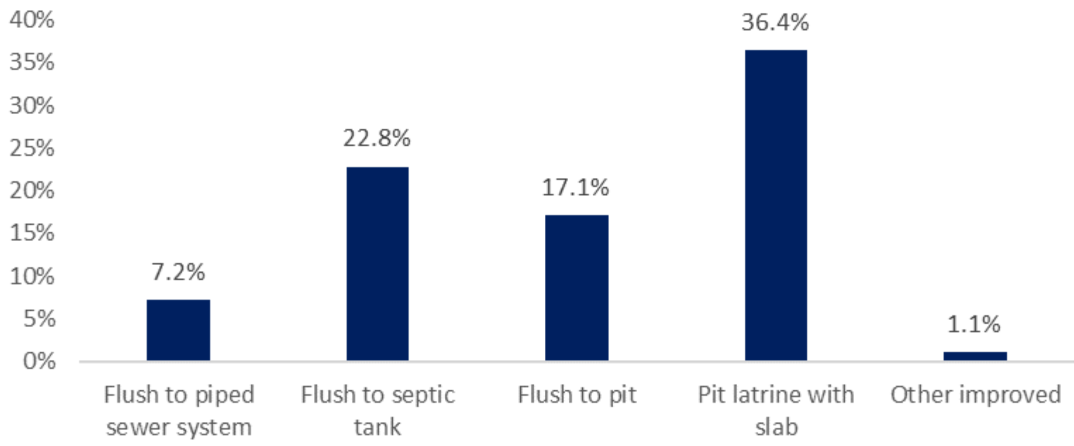
Source: World Bank, produced from BBS/UNICEF (2019).
Note: HHs = households.

2.5.1.2 Access to safe household sanitation

Nearly 85 percent of the population in Bangladesh had access to improved sanitation facilities in 2019, but 20 percent of the population shared sanitation facilities with other households. Therefore, only 65 percent had basic improved non-shared sanitation. The most common type of improved sanitation facility was flush or pour-flush toilet connected to a sewer system, septic tank, or pit. The second most common improved facility was dry pit latrine with slab (figure 2.15). Access to improved sanitation facilities varied from 67 percent among the poorest quintile of households to 97 percent among the richest quintile. A little over 15 percent had unimproved sanitation including 1.5 percent practicing open defecation.

Far from all households with improved non-shared sanitation had safely managed sanitation. Safely managed sanitation means that excreta are safely treated in situ or transported and treated off-site. According to WHO/UNICEF, there are three practical options for safe management: excreta are removed through sewer lines and treated off-site at wastewater treatment plants; excreta are emptied from septic tanks and pits and treated offsite at facilities designed for fecal sludge; or excreta are treated and disposed of in situ in septic tanks with appropriate leach fields or in latrine pits that are covered and left undisturbed when full (UNICEF/WHO 2019).

Figure 2.15 Access to improved sanitation in Bangladesh, 2019 | *Percent of population*



Source: World Bank, produced from BBS/UNICEF (2019).

The Bangladesh MICS 2019 also reports on households' access to handwashing facilities: 75 percent of the population had access to a place of handwashing with soap and water present on household premises while 25 percent did not have a place with such items.

2.5.1.2 Health effects of microbiological pollution

An estimated 72–95 percent of diarrheal disease morbidity and mortality is due to inadequate drinking water, sanitation, and hand hygiene in Bangladesh (table 2.15). The range reflects uncertainties about the magnitude of risk of disease from various types of drinking water (see appendix F). Individually, inadequate drinking water is associated with the largest attributable fraction of diarrheal disease.

Table 2.15 Attributable fractions of diarrheal disease from inadequate WASH in Bangladesh, 2019

	Low (percent)	High (percent)
Inadequate drinking water	54.1	88.0
Inadequate sanitation	31.2	53.3
Inadequate handwashing with soap	11.6	11.6
Inadequate drinking water, sanitation, and hand hygiene	72.1	95.0

Source: World Bank.
Note: The joint attributable fraction of WASH is less than the sum of the individual attributable fractions.

Annual deaths from inadequate WASH are estimated at 34–44 thousand in 2019, with a central estimate of 39 thousand (table 2.16). The main source of death is diarrheal disease including typhoid and paratyphoid. Deaths from ALRI due to inadequate handwashing and infectious disease mortality from underweight caused by repeated diarrheal infections in early childhood are about the same.

Table 2.16 Annual deaths from inadequate WASH in Bangladesh, 2019

	Low	Central	High
Diarrheal disease	23,741	27,518	31,295
Typhoid/paratyphoid	5,672	6,574	7,476
ALRI from inadequate handwashing	2,792	2,792	2,792
Infectious diseases from underweight	2,401	2,783	3,165
Total a	**34,079**	**39,057**	**44,034**

Source: World Bank.
Note: [a] Adjusted for multiple risk factors.

Inadequate drinking water, sanitation, and hygiene also caused an estimated 0.8–1.1 billion days lived with illness in 2019. Diarrheal disease accounts for 98 percent of the days (table 2.17).

Table 2.17 Estimated days lived with illness from WASH in Bangladesh, 2019 | *Millions of days*

	Low	Central	High
Diarrheal diseases	789	915	1,040
Typhoid/paratyphoid	7.6	8.8	10.0
ALRI	6.5	6.5	6.5
Total days of disease from WASH	**803**	**930**	**1,057**

Source: World Bank.

2.5.1.3 Cost of microbiological pollution

Microbiological pollution associated with inadequate drinking water, sanitation, and hygiene is estimated to cost in the range of Tk 619–805 billion in 2019, with a central estimate of Tk 712 billion (see appendixes H and I). This is equivalent to 2.0–2.7 percent of GDP in 2019, with a central estimate of 2.4 percent (table 2.18).

Table 2.18 Cost of health effects of inadequate WASH, 2019 | *Tk, billions*

	Low	Central	High
Cost of mortality	433	496	559
Cost of morbidity	187	216	246
Total cost	619	712	805
Percent equivalent of 2019 GDP	2.10	2.41	2.73

Source: World Bank estimates.

2.5.2 Arsenic exposure

Arsenic in drinking water from tubewells continues to be a health concern in Bangladesh. The MICS 2019 survey included measurements of arsenic concentrations in drinking water in over 12,000 households. The survey found that 17 percent of households had arsenic concentrations in drinking water exceeding the WHO guideline of 10 parts per billion (ppb) (μg/L) and 11 percent of households had concentrations exceeding the Bangladeshi standard of 50 ppb. While the percentage of households with elevated arsenic concentrations in drinking water has declined somewhat since the measurements from MICS 2009 and MICS 2012–13 (BBS/UNICEF 2010; 2014), the arsenic prevalence still poses a significant health risk in several divisions, particularly in Chattogram and Sylhet.

2.5.2.1 Health effects of arsenic exposure

Exposure to arsenic in drinking water has been found to be associated with various health effects including skin lesions (Argos et al. 2011; Karagas et al. 2015); cancer, kidney and liver failure, and ulcer (FAO et al. 2010); and neurological impairments such as poor cognitive performance, reduced intellectual function, learning deficits, mood disorders, visual, speech, attention, and memory disturbances (Brinkel et al. 2009; Tyler and Allan 2014). Increased risks of lung and bladder cancer and arsenic-associated skin lesions have been found from ingestion of drinking water with arsenic concentrations below 50 μg/liter (WHO 2011).

Several studies have also documented the effect of arsenic in drinking water on mortality: all-cause and chronic disease mortality (Argos et al. 2010); nonaccidental all-cause mortality, cancers, cardiovascular-disease mortality, and infectious-disease mortality (Sohel et al. 2009); heart-disease mortality (Chen et al. 2011); lung-disease mortality (Argos et al. 2014); mortality in children (Rahman et al. 2013); and stroke mortality (Rahman et al. 2014). Elevated risks of all-cause mortality in relation to arsenic concentrations in drinking water are presented in table 2.19.

Table 2.19 Risk of mortality from arsenic in drinking water

Arsenic (μg/liter)	Hazard ratio (95% CI)	
	Nonaccidental all-cause mortality in population 15+ years [a]	All-cause mortality in population 18+ years [b]
≤ 10	1.00	1.00
10–50	1.16 (1.06–1.26)	1.34 (0.99–1.82)
50–150	1.26 (1.18–1.36)	1.09 (0.81–1.47)
> 150	1.36 (1.27–1.47)	1.68 (1.26–2.23)

Sources: [a] Sohel et al. 2009; [b] Argos et al. 2010.
Note: CI = Confidence Interval.

Based on the arsenic measurements from MICS 2019 and the mortality risks presented above, arsenic in drinking water in Bangladesh is estimated to have caused 30,629–50,051 deaths with a central estimate of 40,340 deaths in 2019.[20] Nearly two-thirds of the deaths are among the 7 percent of the population with arsenic concentrations exceeding 150 ppb (or μg/L), and one-quarter are among the 6 percent of the population with arsenic concentrations between the WHO guideline (10 ppb) and Bangladeshi standard (50 ppb) (table 2.20). Arsenic in drinking water also caused 1.2–2.4 billion days of illness per year.[21]

Table 2.20 Estimated annual deaths from arsenic in drinking water, 2019

Arsenic (µg/liter)	Population exposure distribution (percent)	Estimated deaths from arsenic in household drinking water		
		Low	Central	High
≤ 10	83.2	0	0	0
10–50	6.1	6,691	10,528	14,366
50–150	3.6	6,416	4,330	2,244
> 150	7.1	17,522	25,481	33,441
Total	**100.0**	**30,629**	**40,340**	**50,051**

Source: World Bank.

2.5.2.2 Cost of arsenic in drinking water

The health effects had a cost of Tk 520–917 billion with a central estimate of Tk 712 billion (see appendixes H and I). This was equivalent to 1.8–3.0 percent of GDP in 2019, with a central estimate of 2.4 percent. Cost of mortality and morbidity constituted 72 percent and 28 percent of total cost respectively (table 2.21).

Table 2.21 Cost of health effects of arsenic in drinking water in Bangladesh, 2019 | *Tk, billions*

	Low	Central	High
Cost of mortality	389	512	635
Cost of morbidity	131	200	282
Total cost	520	712	917
Percent equivalent of 2019 GDP	1.76	2.41	3.11

Source: World Bank.

2.6 Health effects in children

Environmental pollution affects children and adults differently. Many health effects are the result of long-term exposure to pollution over many years that are first experienced in adulthood. This includes cardiovascular disease, lung cancer, COPD, and type 2 diabetes from $PM_{2.5}$ air pollution, cardiovascular disease from lead exposure, and chronic health effects and mortality from arsenic. The health effects of pollution experienced by children estimated in this report are acute illnesses including lower respiratory infections from $PM_{2.5}$ air pollution, diarrheal infections from inadequate drinking water, sanitation, and hygiene, and cognitive impairment from lead exposure.

Using the same data and methodologies as in the previous sections, it is estimated that environmental pollution caused nearly 20,000 deaths, 345 million days of illness, and the loss of nearly 20 million IQ points among children in Bangladesh in 2019 (table 2.22). Ambient air pollution, household air pollution, and inadequate drinking water, sanitation, and hygiene each caused about one-third of the deaths, while 95 percent of days of illness were caused by inadequate drinking water, sanitation and hygiene. As many as 85 percent of the deaths were among children 0–4 years of age and 80 percent of the days of illness were among children 5–17 years of age. Estimation of IQ loss from lead exposure was restricted to children 0–4 years of age but may to some extent also affect older children.

Table 2.22 Annual deaths and illness in children from environmental risk factors in Bangladesh, 2019

	Deaths, 2019			Days of illness, 2019 (millions)		
	Children 0–4 years	Children 5–17 years	Children 0–17 years	Children 0–4 years	Children 5–17 years	Children 0–17 years
Ambient air pollution	6,543	453	6,996	3.3	3.2	6.6
Household air pollution	6,063	378	6,441	3.4	3.0	6.4
Lead (Pb) exposure – lost IQ points [a]				19.7	0	19.7
Drinking water, sanitation, and hygiene	3,973	2,173	6,146	64	268	332
Total	**16,579**	**3,004**	**19,583**	**91**	**275**	**365**

Source: World Bank.
Note: [a] IQ points lost, millions.

The estimated cost of the health effects in children from environmental pollution was Tk. 1,356 billion in 2019, equivalent to 4.6 percent of Bangladesh's GDP that year. This is 26 percent of the total cost in all age groups. As much as 76 percent of the cost of health effects in children is from the loss of IQ points from lead exposure, and as much as 92 percent of the cost was among children 0–4 years of age, demonstrating the vulnerability of the youngest children to pollution (table 2.23).

The estimated health effects in children are conservative. Due to data constraints the estimates do not include health effects of pre-natal and early childhood exposure to arsenic. Neither do they include health effects of air pollution other than lower respiratory infections and neonatal disorders from $PM_{2.5}$. Studies have, however, found evidence of adverse birth outcomes such as preterm birth and low birthweight and impaired neurodevelopment, IQ loss, and stunting in early childhood from prenatal and childhood exposure to various air pollutants. These health effects impair educational outcomes and lifetime earnings and could be substantial in view of ambient air pollution levels and the high prevalence of household solid fuel use in Bangladesh.

Neither do the estimates include health effects in children from exposure to chemicals other than lead. Health effects in children from other chemicals include neurotoxic effects of mercury and endocrine disrupting chemicals such as polybrominated diphenyl ether and organophosphates as well as adverse birth outcomes from prenatal exposure to cadmium. Long term exposure to cadmium and several endocrine disruptive chemicals have also been found to have cardiovascular disease effects in adults.

Table 2.23 Estimated annual cost of environmental health effects in children in Bangladesh, 2019

	Cost (Tk, billions), 2019			Cost (% of GDP), 2019		
	Children 0–4 years	Children 5–17 years	Children 0–17 years	Children 0–4 years	Children 5–17 years	Children 0–17 years
Ambient air pollution	83	6	90	0.28	0.02	0.30
Household air pollution	77	5	83	0.26	0.02	0.28
Lead (Pb) exposure – lost IQ points	1,029	0	1,029	3.49	0.00	3.49
Drinking water, sanitation, and hygiene	65	90	155	0.22	0.30	0.53
Total	**1,255**	**101**	**1,356**	**4.25**	**0.34**	**4.59**

Source: World Bank.

2.7 Conclusions and recommendations

Over 270,000 people are estimated to have died in Bangladesh in 2019 from the environmental health risks assessed in this report.[22] This was over 32 percent of all deaths in the country.[23] Fifty-three percent of the deaths were from ambient and household $PM_{2.5}$ air pollution. Adult lead (Pb) exposure and inadequate drinking water, sanitation, and hygiene caused 21 percent and 26 percent of total deaths, respectively. The environmental health risks also caused 5.2 billion days lived with illness in 2019, and, additionally, impaired intelligence among children amounted to a loss of 20 million IQ points (table 2.24).

Table 2.24 Annual deaths and days of illness from environmental risk factors in Bangladesh, 2019

	Deaths			Days of illness (millions)		
	Low	Central	High	Low	Central	High
Ambient air pollution	87,079	90,620	95,099	1,110	1,153	1,208
Household air pollution	62,215	68,866	74,278	1,338	1,457	1,559
Lead (Pb) exposure	59,452	61,800	63,565	403	419	431
Lead (Pb) exposure – children (lost IQ points) [a]				18.9	19.7	20.4
Lead (Pb) exposure – adults	59,452	61,800	63,565	403	419	431
Drinking water, sanitation, and hygiene	64,708	79,397	94,085	1,934	2,656	3,492
Microbiological pollution	34,079	39,057	44,034	803	930	1,057
Arsenic in drinking water	30,629	40,340	50,051	1,131	1,726	2,436
Total	**273,454**	**300,682**	**327,027**	**4,785**	**5,685**	**6,690**
Adjusted total [b]	**249,713**	**272,422**	**294,156**	**4,370**	**5,151**	**6,018**

Source: World Bank.
Note: [a] IQ points lost, millions. [b] Adjusted for multiple risk factors using method in appendix J.

Annual deaths from environmental risk factors are higher than the total number of deaths caused by natural disasters between 1971 and 2021 (box 2.1). For comparison purposes, road traffic accidents in Bangladesh caused at least 5,227 deaths in 2019 (Kundu, Banna, and Sayeed 2020).

Box 2.1 Cost of natural resources degradation and natural disasters

The World Bank estimated the costs of natural resources degradation and natural disasters, which have a significant impact on human health and impose substantial costs on the economy of Bangladesh. Because of data constraints, the analysis focused on the costs of forest loss, agricultural soil nutrient depletion, and natural disasters. The analysis of these three factors found an estimated annual cost from Tk. 702–1.510 billion in 2019, equivalent to 2.7–5.9 percent of GDP that year, with a midpoint estimate of Tk. 1.106 billion or 4.4 percent of GDP (table B2.1).

Table B2.1 Cost of natural resource degradation and natural disasters, 2019

	Annual cost (Tk, billions)			Annual cost (% of GDP)		
	Low	Midpoint	High	Low	Midpoint	High
Agricultural land nutrient depletion	310	345	379	1.2	1.4	1.5
Forest losses and degradation	9.3	9.3	9.3	0.0038	0.0327	0.0364
Natural disasters	383	752	1,122	1.5	3.0	4.4
Total cost	**702**	**1,106**	**1,510**	**2.7**	**4.4**	**5.9**

The analysis of impacts of natural resource degradation and natural disasters on the economy and human health found the following:

- Agricultural soil depletion is mainly caused by using crop residue as household fuel and the limited transition to modern and clean cooking fuels and technologies. Potassium is the most sever nutrient deficiency, responsible for an estimated loss of 10-13 million tonnes per year or 27-36 percent of current rice grain production.
- Forest loss and degradation also pose a significant threat to Bangladesh's economy and population —for example, through the spread of zoonotic diseases, increased vulnerability to climate change and loss of natural assets that are essential to livehihoods. With only a little over 14 percent forest cover, a high population density and a high share of land allocated to agricultural crop cultivation, forests play a critical role in protecting against cyclones, landslides, and erosion

allocated to agricultural crop cultivation, forests play a critical role in protecting against cyclones, landslides, and erosion in the Hill forest area and providing resources such as fuelwood, bamboo, and timber.

- Between 1971 and 2021, natural disasters caused a total of 220,181 deaths in Bangladesh (including from floods, cyclones, and other storms, extreme temperature, landslides, earthquakes, and droughts) (World Bank estimates based on EM-DAT 2022). Even mild and moderate droughts can have a significant cost when they affect large areas of the country. The 2021 Global Climate Risk Index ranked Bangladesh as the world's seventh-most-affected country in 2000–19 (Germanwatch 2021). In addition, Bangladesh ranks second highest in the natural hazard risk index, which also covers hazards not related to climate (EC DRMKC). To estimate the cost of natural disasters, the Bank reviewed the estimates from four sources for flood and cyclone, drought, and "other" natural disasters: ADB (2016), BBS (2022c), EM-DAT (2022), and ESCAP (2021). However, there was a significant discrepancy between the cost estimates for droughts and "other" between the two available sources (BBS 2022c; ESCAP 2021), and extensive risks and indirect loss were only estimated by ESCAP 2021. Thus, the Bank limited its estimates to the expected average annual costs of flood and cyclone, without including extensive risks and indirect costs. This gives expected average annual cost in the range of Tk. 211–272 billion with a midpoint estimate of Tk. 241 billion. The cost is equivalent to 0.8–1 percent of GDP in 2019, with a midpoint estimate of 0.9 percent. The 2022 Bangladesh Country Climate and Development Report (CCDR) provides additional data on exposure and vulnerability to natural hazards in Bangladesh, which "pose grave risk to communities and their assets, causing disproportional damage and disrupting lives and livelihoods" (World Bank 2022).

The World Bank did not conduct a cost-benefit analysis of potential interventions to address those issues because of limited quantitative data. However, the CCDR has identified key interventions to address natural disasters in Bangladesh, which are closely associated with climate change adaptation. Additionally, the World Bank is preparing a policy note on agricultural soil depletion.

Source: World Bank

The health effects from the environmental risk factors can be monetized by using standard valuation techniques to provide an economic and welfare perspective on the magnitude of these effects. The annual cost of the environmental health effects is estimated in the range of Tk 4.8–5.6 trillion in 2019, with a central estimate of Tk 5.2 trillion. This cost is equivalent to 16.2–19.0 percent of Bangladesh's GDP in 2019, with a central estimate of 17.6 percent (table 2.25).

About 42 percent of the cost is from ambient and household $PM_{2.5}$ air pollution; 33 percent from lead exposure; and 25 percent from inadequate drinking water, sanitation, and hygiene. Over half of the cost of lead exposure is from loss of IQ points among children. Half of the cost of inadequate drinking water, sanitation, and hygiene is from arsenic in drinking water. A comparison of these estimates of health effects and costs to the estimates in the 2018 Country Environmental Analysis is provided in box 2.2.

Box 2.2 Consistency with the 2018 CEA

The 2018 Country Environmental Analysis (CEA) reported over 80,000 deaths from environmental risk factors in urban Bangladesh at a welfare cost equivalent to 3.7 percent of GDP including cost of morbidity (World Bank 2018). The estimate implies a death rate of 146 per 100,000 population in urban areas. The death rate from environmental risk factors estimated in this report for all of Bangladesh is 167 per 100,000 population. The urban death rate from the CEA 2018 are lower than the national estimate due to several factors: (a) the death rate from household air pollution is lower than the national estimate due to lower rates of solid-fuel use for cooking in urban than in rural areas; (b) the death rate from microbiological pollution in WASH is lower than the national estimate due to a lower fatality rate from diarrheal disease in urban than in rural areas; and (c) the CEA 2018 does not estimate urban mortality from lead exposure.

Three main factors explain the difference in the welfare cost of pollution—3.7 percent of GDP versus 17.6 percent of GDP for the national estimate. The factors are (a) the national population is 2.7 times the urban population and explains nearly 60 percent of the difference in cost; (b) the cost of IQ losses in children from lead exposure at 3.5 percent of GDP at the national level is not included in the 2018 CEA other than as a minor cost of 0.03 percent of GDP associated with urban used lead-acid battery (ULAB) sites; and (c) the national cost estimate accounts for higher morbidity cost of pollution than the 2018 CEA accounts for.

Source: World Bank.

Table 2.25 Estimated annual cost of environmental health effects in Bangladesh, 2019

	Cost (Tk, billions), 2019			Cost (percent of GDP), 2019		
	Low	Central	High	Low	Central	High
Ambient air pollution	1,291	1,343	1,409	4.38	4.55	4.77
Household air pollution	1,007	1,112	1,198	3.41	3.77	4.06
Lead (Pb) exposure	1,785	1,860	1,918	6.05	6.30	6.50
Lead (Pb) exposure - children (lost IQ points)	985	1,029	1,063	3.34	3.49	3.60
Lead (Pb) exposure – adults	800	832	855	2.71	2.82	2.90
Drinking water, sanitation, and hygiene	1,139	1,424	1,722	3.86	4.82	5.83
Microbiological pollution	619	712	805	2.10	2.41	2.73
Arsenic in drinking water	520	712	917	1.76	2.41	3.11
Total	**5,221**	**5,739**	**6,247**	**17.7**	**19.4**	**21.2**
Adjusted total [a]	**4,768**	**5,199**	**5,619**	**16.2**	**17.6**	**19.0**

Source: World Bank.
Note: [a] Adjusted for multiple risk factors using the method in appendix J.

Nationwide population-weighted ambient $PM_{2.5}$ in Bangladesh is among the highest in the world and as many as 74 percent of the population used solid fuels as their primary cooking fuel in 2019, causing enormous health effects among the population. Despite substantial declines in lead exposure over the last two decades, BLLs in children and adults remain at very high levels, and 17 percent of the population rely on drinking water with arsenic concentrations above the WHO guideline of 10 ppb.

In sum, environmental health risk exposure levels in Bangladesh are at critically high levels, and aggregate health effects and their costs are substantial. Controlling and preventing outdoor ambient $PM_{2.5}$ pollution should be a priority. The focus should be on reducing $PM_{2.5}$ concentrations from current levels of about 64 μg/m^3 to WHO's Interim Targets I–IV of 35 to 10 μg/m^3 and eventually to WHO's annual AQG of 5 μg/m^3. Control of household air pollution is also a high priority. With three-quarters of the population using solid fuels for cooking, health benefits from improving ambient $PM_{2.5}$ will be rather minimal unless household air pollution is controlled simultaneously. Clean fuels and technologies—such as LPG, natural gas, and electricity—are by far the most effective interventions but continued expansion of the ICS programs, and promotion of dual-burner stoves in particular, will continue to be important for households that cannot afford cooking with LPG or electricity and also serve an important role in conserving scarce fuel wood and reduce the use of agricultural residue for cooking.

Considering recent evidence of the severity of impacts of lead on children and adults, representative BLL measurement studies should be undertaken along with identification of sources of lead exposure. Improvements should be continued in the water and sanitation sector, with emphasis on safely managed drinking water and sanitation with safely managed disposal and treatment of fecal sludge. Further analysis is needed to assess the impacts of salinity intrusion and other highly poisonous heavy metals in water, such as lead, mercury, and cadmium. Additional studies are also needed to better understand the economic and distributional impacts of the four categories of environmental health risks covered by this chapter.

The health effects and costs of environmental pollution estimated in this chapter should be considered conservative. $PM_{2.5}$ ambient and household air pollution has additional health effects such as increased incidence of preterm birth, low birth weight and stunting in early childhood. These health effects are associated with impaired cognitive development, IQ, and compromised human capital development and lifetime earnings potential. $PM_{2.5}$ air pollution has also been found to affect labor productivity in both manufacturing and service sectors in many countries. Moreover, the health effects of air pollution estimated in this chapter do not incorporate health effects of other air pollutants that may be additional to the effects of $PM_{2.5}$. For lead exposure, additional impacts that may not be fully captured by the effect on IQ and lifetime income include the effects of exposure in early childhood on learning productivity in school and subsequent impairment of labor productivity.

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Endnotes

2 $PM_{2.5}$ are particulates with a diameter smaller or equal to 2.5 micrometers (μm).

3 See annex 2G for the methodology for calculations of years of disability and days of illness.

4 World Bank estimates based on BBS/UNICEF (2019) and BBS (2019).

5 https://www.bondhufoundation.org/ongoing-project/bondhu-chula/

6 https://idcol.org/home/ics

7 Personal exposure was measured for women using each of the three types of IDCOL stoves. The exposure of 179 μg/m³ is the weighted average based on sales of each type. See Berkeley Air Monitoring Group (2022).

8 Ambient $PM_{2.5}$ deducted from personal exposure was a rural annual average of 57 μg/m3 for the study by Shahriar et al. (2021) because this study included measurements both in the dry and wet seasons. Ambient $PM_{2.5}$ deducted from personal exposure for the study by Berkeley Air Monitoring Group (2022) was 112 μg/m³. This was average ambient $PM_{2.5}$ during the dry season measurement period in the five divisions of the study (mainly January–February 2022).

9 See annex 2G for the methodology for calculations of years of disability and days of illness.

10 The standard deviations for the population of Bangladesh were estimated from mean BLLs and standard deviations reported in Ericson et al. (2021) from nearly 300 BLL measurement studies in 30 low- and middle-income countries (LMICs) for children and 355 studies in 36 LMICs for adults.

11 The effects on BLLs were estimated using the Integrated Exposure Uptake Biokinetic (IEUBK) Model Version 2 developed by the USEPA. The model has for instance been applied to predict BLLs from remediation of Pb contaminated soil (Brown et al. 2023) and from dietary and soil/dust intake of Pb in China (Li et al. 2016). Model parameters were adjusted to reflect the situation in Bangladesh with respect to time spent outdoors per day (4.8 hours), daily quantity of drinking water intake (0.82 liters), and soil ingested (0.168 grams per day) by a two-year-old child.

12 This is estimated assuming a two-year-old child's food consumption of 300 g/day or a little less than half of an adult's food consumption (800 g/day) in Bangladesh.

13 Intelligence quotient (IQ) is a score on standardized tests designed to assess intelligence.

14 The log-linear function is $\Delta IQ = \beta [\ln(BLL+1)]$ with $\beta = 3.246$ for childhood lifetime BLLs prior to IQ testing (see annex 2C).

15 Loss of IQ points is calculated for all children, with annual IQ loss calculated as $\Delta IQ / 5$ by assuming that the children's IQ points are lost in the first five years of life. The GBD 2019 limits the estimate of health effects in children to children for whom Pb exposure causes idiopathic developmental intellectual disability (IQ score below 70).

16 IQ losses are 17.5–19.2 million points with a TMREL of 2 μg/dL.

17 See annex 2G for the methodology used to calculate days of illness.

18 The present value is estimated based on a discount rate of 5 percent and a long-term real annual future income growth of 2.5 percent. The discount rate is twice the income growth rate as proposed by World Bank (2016a).

19 Appropriate methods include boiling, bleaching/chlorination, filtering, and solar disinfection.

20 Deaths from arsenic in drinking water is baseline all-cause deaths (or nonaccidental all-cause deaths) in 2019 from the GBD 2019 for Bangladesh multiplied by the attributable fraction (AF) of these deaths due to arsenic. The AF is calculated using the attributable fraction formula in annex 2E.

21 Days of illness (D), for each type of illness, are calculated as follows: $D = M * YLDs \text{ per death} * 365 / w$ where M is deaths from arsenic exposure, YLDs per death is from the Global Burden of Disease 2019 (GBD 2019) for Bangladesh, and w is the disability weight of illness from the GBD 2019.

22 This annual rate is higher than the total number of deaths caused by natural disasters between 1971 and 2021. In that period, natural disasters caused a total of 220,181 deaths in Bangladesh (including from floods, storms, temperature extremes, landslides, earthquakes, and droughts). The World Bank estimates were produced from EM-DAT (2022).

23 For comparison purposes, road traffic accidents in Bangladesh caused at least 5,227 deaths in 2019, and an estimated 75,617 deaths were attributed to diabetes in 2021 (ICCDR,B; Satyajit, Banna, and Abu Sayeed 2020).

CHAPTER 3. BANGLADESH'S ENVIRONMENTAL GOVERNANCE FRAMEWORK

3.1 Introduction

Tackling pollution and reducing its severe health effects are fundamental to achieving Bangladesh's broader development goals. This chapter analyzes the design and effectiveness of environmental regulations and institutions in Bangladesh, particularly for addressing priority challenges in environmental health and pollution management. It builds on and complements the institutional analysis from the 2018 Country Environmental Analysis (CEA) (World Bank 2018).

The methodology used to develop this chapter consisted of (a) a desktop review of official documents, including existing laws and regulations, policies, guidelines, plans and annual reports of government agencies; (b) a review of results and lessons learned from recently completed analytics and operations financed by Development Partners (DPs); and (c) discussions with Government of Bangladesh (GoB) officials and other stakeholders as part of the CEA consultations. Among those stakeholders, the Bank team conducted semi-structured interviews with representatives from industry associations, academia, Civil Society Organizations (CSOs), and DPs. These interviews provided diverse perspectives on opportunities to strengthen Bangladesh's institutional framework for environmental management.

3.2 Legal framework for environmental management in Bangladesh

Bangladesh's environmental legal framework is shaped by more than 100 acts, rules, policies, and plans. Article 18A of Bangladesh's Constitution, introduced in 2011 through the 15th Amendment, recognizes environmental protection as a fundamental right and establishes that the state must "endeavor to protect and improve the environment and to preserve and safeguard the natural resources, biodiversity, wetlands, forests and wildlife for the present and future citizens." The country's legislation covers a wide range of environmental and natural resource issues, including air, noise, and water pollution, forests, biodiversity conservation, and wetland management. Additional instruments focus, among others, on agriculture and livestock, fisheries, land degradation, water resource management, disaster risk management, labor and occupational risks, pesticides, renewable energy and energy efficiency, industry, and trade. Figure 3.1 summarizes the chronological development of major environmental policies and regulations since the adoption of Bangladesh's first environmental policy in 1992. The list is not exhaustive and focuses on the environmental priorities covered by the CEA.

Complementing the 2018 CEA, except for the Environment Conservation Act (ECA) 1995, this chapter emphasizes regulations approved from 2018 to 2023, especially those instruments related to the country's environmental priorities identified in Chapters 2 and 7 (air pollution, water supply and sanitation, lead and other chemicals, and plastic waste).

Environment Conservation Act. The ECA 1995 (amended in 2000, 2002, and 2010) remains the backbone of the legal framework for environmental protection in Bangladesh. The law aims at (a) promoting environmental conservation, (b) improving the country's environmental quality standards, and (c) controlling and mitigating environmental pollution. The ECA includes provisions on (a) environmental standards, including limits on noise, air pollution emissions, and discharges into water and soil; (b) environmental clearance of industries, infrastructure, and development projects; and (c) remedial measures and compensation from those responsible for ecosystem damages or emitting and discharging pollutants above permissible levels. The act also set forth sanctions for noncompliance with its provisions.

Despite its previous amendments, the ECA omits critical issues in environmental management. A comprehensive reform to the ECA is needed to ensure a transformative change towards greening the economy and ensuring sustainable development. A new amendment and corresponding rules should include provisions to: (a) expand the DoE services and incorporate a new Environment cadre in the Bangladesh Civil Service (BCS); (b) promote circular economy, eco-design, and market-based policy instruments; (c) modernize and make enforcement activities more efficient, including clear provisions to implement the polluters pay principle and set adequate sanctions and incentives for compliance with the ECA provisions, based on the magnitude of the risk or actual damage, recidivism, and polluter's payment capacity; (d) mobilize green financing by establishing a permanent Environment Fund, which could receive resources from the compensation for environmental damage envisaged in Article 7 of ECA and eventually from environmental taxes and imposed fines; (e) improve stakeholder engagement in environmental decision-making; (f) require Strategic Environmental Assessment (SEA) for policies, plans and programs; (g) set the mandates and foundations for further regulations on Extended Producer Responsibility (EPR), Payment for Ecosystem Services (PES), and Living Modified Organisms (LMO), among other themes.

Figure 3.1 Development of environmental policies and regulations in Bangladesh

National Environmental Policy 1992
National Energy Policy 1995
Environment Conservation Act 1995
National Environment Management
Action Plan (1995–2005)
Water Supply and Sanitation Act 1996
Environment Conservation Rules 1997

Shipbreaking and Recycling Rules 2011
Hazardous Waste Management and Ship-Breaking Waste Management Rules 2011
Sustainable and Renewable Energy Development Authority (SREDA) Act 2012
Brick Manufacturing and Brick Kilns Establishment Act (BMBKEA) 2013
Bangladesh Water Act 2013
National River Conservation Act 2013
Bangladesh Country Action Plan for Clean Cookstoves 2013
Energy Efficiency & Conservation Rule 2014
Energy Efficiency & Conservation Master Plan Up to 2030 (2014)
Bangladesh Electricity & Energy Research Council Act 2015
Bangladesh Standards and Guidelines for Sludge Management 2015
Bangladesh Country Investment Plan for Environment, Forestry, and Climate Change (2016–2021)

NDC 2021
EIA Guidelines for Industries 2021
E-Waste Management Rules 2021
Solid Waste Management Rules 2021
Air Pollution Control Rules 2022
Environment Conservation Rules 2023
Energy Efficiency and Conservation Rules 2016 (Amended 2023)
Environment and Biodiversity Conservation of Saint Martin's Island and Eco-Friendly Tourism Guidelines 2023

1990 — 2000 — 2010 — 2015 — 2020

ECR 1997 (Amended Feb, Aug 2002)
National Industrial Policy 2005
Environment Court Act 2000
ECA (Amended 2000 and 2002)
ECR 1997 (Amended 2005)
Renewable Energy Policy 2008
Medical Waste Management Rules 2008
Ecologically Critical Areas Gazette 2009
Mobile Court Act 2009
BEZA Act 2010
Bangladesh Climate Change Trust Act 2010
Balumahal and Soil Management Act 2010
Speedy Increase of Electricity & Fuel (Special Provision) 2010
National 3R Strategy 2010
Environment Court Act 2010
ECR 1997 (Amended 2010)
ECA 1995 (Amended 2010)

Ecologically Critical Area Rules 2016
National Industrial Policy 2016
Energy Efficiency and Conservation Rules 2016
Energy Audit Rules 2016
Petroleum Act 2016
Bangladesh Biodiversity Act 2017
ECR 1997 (Amended Feb 2017)
Pesticide Act 2018
Bangladesh Water Rules 2018
Bangladesh Ship Recycling Act 2018 (ratifying Hong Kong International Convention for safe and environmentally sound recycling of ships 2009)
National Environment Policy 2018
Roadmap and Action Plan for Implementing Bangladesh's Nationally Determined Contribution (NDC) 2018
BMBKEA 2013 (Amended 2019)
Air Pollution Control Guideline 2019 (For Dhaka)

Sources: Faroque and Hasan 2014; MoEFCC; World Bank 2018.

Environment Conservation Rules (ECR). In 2023, the MoEFCC approved the new ECR (ECR 2023), which strengthened requirements and clarified procedures for industries and project units to assess and manage environmental and social impacts associated with their activities. The new ECR updated the water quality and sewerage standards, as well as waste emissions and liquid waste standards for industries and projects. Standards for ambient air were moved to the Air Pollution Control Rules (APCR), 2022. The new ECR, as in the 1997 version, kept limited provisions on the DoE's responsibilities of policy formulation, data collection, environmental quality monitoring and enforcement (including, for example, the use of new technologies for oversight activities). The ECR 2023 detailed provisions for project scoping, categorization, site clearance, environmental assessment (including social issues), cross-sector and stakeholder consultations, among others. Additionally, the ECR 2023 regulated access to information and stakeholder participation throughout the environmental clearance process, particularly for those activities that require a full Environmental Impact Assessment (EIA). Although the ECR 2023 is expected to improve the environmental clearance (EC) process, additional guidelines are required to clarify assessment criteria and procedures related to key themes as described in Chapter 4 of the CEA.

Air Pollution Control Rules (APCR). The APCR 2022 sets national air quality standards based on WHO Air Quality Guidelines (Interim Goals), emissions limits and technical specifications for key sectors, mandates and coordination mechanisms among relevant line ministries to control both household and outdoor air pollution. The rules elevated the air quality management (AQM) leadership beyond the environment sector by establishing the National Committee on Air Pollution Control (NCAPC), a multi-sector decision-making body presided over by the Cabinet Secretary to coordinate the APCR implementation and instructing relevant agencies on specific interventions to comply with the new rules. The NCAPC is mandated, for example, to impose emergency measures in case of heavy air pollution, such as restricting activities of industries or projects, vehicles, or any source of air pollution in a certain area and closure of educational institutions. The APCR also envisages the objectives and minimum requirements of its implementation management tools, such as a National Air Quality Management Plan (also covering interventions and targets for household air pollution), a degraded airsheds declaration and management plan, the publication of a list of high air polluting industries and activities, prevention plans, and monitoring and control systems.

Although APCR 2022 represents an important achievement of AQM in Bangladesh, the rules lack specific provisions on market-based policy instruments, the use of ICT and remote monitoring of emissions in highly polluting industries, and the need to develop evidence to inform policy making (for example, through emissions inventories, chemical composition and source apportionment studies, emission projections). Additional guidelines should be approved to (a) guide enforcement activities related to AQM, particularly on-site inspection by the DoE and mobile courts, (b) gather and disseminate air quality monitoring data, and (c) identify prioritized activities, industries, and projects for monitoring, enforcement and disclosure of emissions-related information.

Other relevant regulatory development for AQM refers to the 2019 Amendment of the Brick Manufacturing and Brick Kilns Establishment Act (BMBKEA) 2013. The amendment set phased targets to reduce the use of clay-fired bricks in public works from 2019 to 2025, except for the construction of the base/sub-base of the highways. However, implementation of this phased reform is delayed. In other sectors, the GoB approved a framework for adopting a market-linked price adjustment system for high-speed diesel (HSD), heavy fuel oil (high-sulfur fuel oil, HSFO) and octane prices in 2024—although similar measures are recommended for other types of fuels. The Power Division amended the 2016 Energy Efficiency and Conservation Rules in 2023 to systematically assess energy-saving potential and improve the energy efficiency of the largest consumers. These energy policies may generate emissions reductions and positively impact air quality.

Regulations on heavy metals and other toxic chemicals. The ECR 2023 sets parameters on lead, mercury, arsenic, cadmium and other chemicals in the waste emissions and water quality standards. The rules also envisage maximum permissible levels of chemicals for key industries, including crude oil, pesticides, textile, fertilizer, paint, and battery manufacturing. Through Statutory Regulatory Orders (SROs), the Bangladesh Standards and Testing Institution (BSTI) sets testing methods and permissible limits for heavy metals in multiple products (for example, fertilizers, pesticides, starch and derived products, refined sugar and other food, solid biofuels, cosmetics, toys, paint, batteries, ceramic and glass dinnerware, and ceramic tiles) (BSTI 2021). Regarding lead, BSTI issued SRO No. 221-Law/2018 with three standards on household and home decoration paints, setting a total lead limit of 90 ppm (parts per million) in paint manufacturing and requiring manufacturers to obtain a license at BSTI.[24] Since 1996, Bangladesh has gradually banned highly toxic pesticides (partially or completely), including the removal of class 1a and 1b pesticides from agriculture use, p,p-dichlorodiphenyltrichloroethane (DDT) and other persistent organic pollutants (POPs). In 2018, the GoB adopted the Pesticide Act, replacing the Pesticides Ordinance 1971 and the Pesticide Rules 1985. The Import Policy Order (2021–2024) issued by the Ministry of Commerce (MoC) bans the importation of industrial sludge and fertilizer, any kind of waste material, and chemicals controlled under the Stockholm Convention on POPs and requires DoE authorization to import ozone-depleting substances.[25]

In 1993, Bangladesh acceded to the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal. However, there was no specific regulation for hazardous waste management within the country, which was partially covered by Hazardous Wastes and Shipbreaking Waste Management Rules, 2011. In 2021, in addition to the overarching Solid Waste Management Rules (SWMR), the MoEFCC adopted the Hazardous (E-Waste) Management Rules (EMR) and SRO No. 45-Act/2021 on battery recycling, which complemented SROs No. 175-Act/2006 and No. 29-Act/2008, covering clearance obligations, disposal of batteries, approved labs, restrictions on financial transactions for used/nonfunctional batteries, among other provisions. The EMR envisage a registration process before the DoE, in addition to the regular EC process, for manufacturing, trading, recycling, and operating other businesses related to electric and electronic equipment; maximum limits for the use of heavy metals and toxic substance in certain electronic products; EPR for collecting and management wastes from electric and electronic equipment; and sanctions for not complying with these regulations.

The DoE is also working on new regulations and amendments, such as the amendment of the Medical Waste Management and Processing Rules, the Chemical Waste Management Rules, the Amendment of the Environment Court Act (ECtA); and the ratification of key international instruments, such as the Minamata Convention on Mercury, the amendment to the Stockholm Convention on Persistent Organic Pollutants.

Water and Sanitation regulations. The Water Supply and Sewerage Authority Act (WSSAA) 1996 regulated the country's WSS framework, envisaging autonomous corporate management structures of Water Supply and Sewerage Authority (WASA). However, industrial effluents are not covered by the WSSAA, and there was no reference for evidence-based, long-term planning for sustainable use and management of water resources. The Bangladesh Water Act 2013 and its subsequent Water Rules 2018 regulate the integrated development, management, abstraction, distribution, use, protection, and conservation of water resources. This legislation provides for the right to water when it is used for the purposes of drinking, sanitation, and sewage disposal, regulates land ownership requirements, surface water, among other themes. In 2023, the Local Government Division adopted national Water Supply and Sanitation (WSS) Guidelines, which must be incorporated in legal framework of urban local government institutions (LGIs) by September 2023 for regulating WSS services at secondary cities (Pourashavas), including criteria and procedures for setting tariffs and service fees. Additionally, the ECA mandates the Director General (DG) of the Department of Environment (DoE) to conduct a drinking water quality surveillance program.

3.3 Institutional framework for environmental management

Several government organizations have an important role in environmental management in Bangladesh, but the MoEFCC and the DoE hold the primary responsibility for environmental protection.

Ministry of Environment, Forest and Climate Change (MoEFCC). The Ministry is the primary agency responsible for environmental management, and it carries out its mandate through the operation of seven specialized agencies: the DoE, Bangladesh Forest Department (BFD), Bangladesh Forest Industries Development Corporation (BFIDC), Bangladesh Forest Research Institute, Bangladesh National Herbarium, Bangladesh Climate Change Trust (BCCT), and Bangladesh Rubber Board (BRB). The **Parliament's Standing Committee on Environment, Forest and Climate Change** has the authority to oversee the functions of the MoEFCC. Parliamentary committees can directly question the minister to elicit information or organize parliamentary commissions to conduct investigations, raise the visibility of policy issues and make recommendations on how to improve the ministry's performance (Ohiduzzaman 2010).

According to the ECA, the **Department of Environment** is the primary agency entrusted with implementing the act. It carries out six key responsibilities: (a) monitoring environmental quality; (b) controlling and monitoring industrial pollution; (c) establishing regulations and guidelines for activities impacting the environment; (d) reviewing environmental impact assessments and managing the environmental clearance process; (e) promoting environmental awareness through public information programs; and (f) coordinating the implementation of a number of international protocols and conventions that Bangladesh has signed (ECA; Ferdous 2017; World Bank 2018). With a broad mandate, the DG of the DoE has the authority to take any necessary measures to meet the objectives of the ECA, including the power to issue written notices to anybody, enlisting their assistance in discharging the DoE's duties. The DG can adopt environmental standards to control and mitigate pollution, issue environmental clearances, and penalize a company or person for not complying with environmental standards or for damaging ecosystems. For example, based on such broad mandate, the DG has ordered industries and projects operating without an Environmental Clearance Certificate (ECC) to suspend their activities or has disconnected those facilities from water, gas, or electricity services. The DG also has legal authority to identify contaminated sites that pose risks to public health, conduct research, and collect, publish, and disseminate information to contribute to environmental awareness and education. Building on the ECA and the ECR, the

DoE must also work on guidelines for the DG mandate to avoid arbitrary decisions and ensure legal certainty for citizens. Those guidelines are also needed for other DoE's enforcement activities (Section 3.5).

The **Ministry of Planning** (MoP), especially through the Planning Commission, is responsible for fostering intersectoral coordination among ministries and setting short-, medium-, and long-term strategic government goals. The MoP plays a powerful role in defining policies and resource allocation to accomplish these objectives, as well as in selecting public investment projects. As part of the MoP, the **Bangladesh Bureau of Statistics** (BBS) is responsible for providing statistical information to guide decision-making and the development process. Under the Bangladesh Environmental Statistics Framework (BESF) 2016–2030, the GoB plans to implement an integrated approach to collecting, analyzing, and disseminating environmental data and information on the basis of national priorities and future plans.

The Finance Division of the **Ministry of Finance** (MoF) is fundamental to develop an Environmental Fiscal Reform and to define fiscal instruments to operationalize the polluter pays and user pays principles. The **National Board of Revenue** (NBR), also under the MoF, collects tax revenues and, therefore, can advise on the use of different market-based instruments to control pollution, including environmental taxes or deposit and refund schemes. NBR is also responsible for the inspection of all chemical imports, keeping records of volumes and quantities of imported products into Bangladesh, including legally imported lead and lead compounds. Such information can be used to identify trends in lead use that should prompt additional government responses. The country's central bank, the **Bangladesh Bank (BB)**, has developed green financing policy and guidelines, established minimum targets of direct green financing for all banks and non-bank financial institutions, and created green concessional lending schemes to promote eligible green investments. Chapter 9 assesses the barriers to accessing these green financing schemes.

The **Ministry of Water Resources** is primarily responsible for the development and management of Bangladesh's water resources, including surface and groundwater. However, there is no central institution governing the entire WSS sector in the country, and there is no formal regulator to approve water and sanitation tariffs—which are low and vary across consumer groups—and monitor service standards and performance of service providers. LGIs have conducted WSS functions through multiple agencies—such as WASAs in the case of City Corporations—in a disconnected and uncoordinated manner based on their own local regulations. LGIs are also tasked with providing services of public health, waste management, road networks, disaster management and urban planning. For this reason, the Ministry of Local Government, Rural Development and Co-operatives (MoLGRDC), which oversees all matters related to LGIs, play a key role in implementing environmental policies issued by MoEFCC.

The core function of the **Ministry of Industries** (MoI) is to issue and oversee industrial policy, including methods and standards through BSTI. The ministry is also a member of various national committees with linkages with environmental management, such as the Climate Change, Climate Finance, and National Rivers Commissions and the recently created NCAPC. The **Ministry of Commerce** (MoC) has a mandate to promote better environmental management of import and export-oriented industries. The Import and Export Control Department, under the MoC, must ensure that imports and exports meet minimum environmental, health, and safety standards, including for harmful substances.

The **Ministry of Agriculture** plays a key role in (a) supporting the development of new technologies to enhance agricultural productivity and distributing agricultural inputs (for example, urea and non-urea fertilizers); and (b) monitoring the content of pollutants and hazardous substances (for example, excessive amounts of lead) in food, including spices, fish and vegetables that have been identified by previous studies as containing high lead levels.

The Bangladesh Road Transport Authority (BRTA), under the **Ministry of Road Transport and Bridges**, issues fitness certificates and conducts vehicle emission inspections, as delegated by the DoE based on ECA. The BRTA is also part of the NCAPC. The **Ministry of Power, Energy and Mineral Resources** is also crucial for improving air quality in Bangladesh because of its mandate over power generation and fuel quality.

The **Ministry of Labour and Employment**, especially through the Department of Inspection for Factories and Establishments (DIFE), is responsible for ensuring the welfare, safety and health of valuable human resources working in various sectors contributing to national development. The Directorate General of Health Services (DGHS), under the **Ministry of Health and Family Welfare,** leads efforts to develop and implement strategies to identify and protect populations at risk, including occupational health hazards such as battery recycling. DGHS can also collect routing health information, which could be expanded to monitor the health effects of environmental risks, such as blood lead levels or hospital admissions associated with air pollution and exposure to hazardous chemicals.

3.4 Institutional shortcomings at MoEFCC and DoE

Even though a reasonably structured institutional framework for environmental governance is in place at the MoEFCC and the DoE, the framework's actual operation is hampered by gaps and shortcomings in its organizational structure, insufficient budgetary and human resources, challenges with coordination across agencies and with local governments, and limited environmental data management and evidence-based decision-making.

3.4.1 Organizational structure

As for the DoE's organizational design perspective, there was an increase in its specialized technical units in the past years, which are comprised of directorates on (a) environmental clearance, (b) monitoring and enforcement, (c) air quality, (d) climate change, (e) natural resource management (NRM), and (f) chemical and waste management. Other units cover administration, planning, information technology and legal matters (appendix K). Outside the Dhaka headquarters, the DoE operates through eight divisional offices (Dhaka, Chattogram, Rajshahi, Khulna, Barisal, Sylhet, Rangpur, and Mymensigh), two metropolitan offices (Dhaka and Chattogram) and 50 district offices. There is no DoE office in the remaining fourteen districts and at the Upazila (subdistrict) level (DoE 2023).

Certain gaps in the DoE's structure might compromise the fulfillment of the DoE's mandate. By merging two key areas of responsibility—environmental quality monitoring and environmental enforcement—under a single directorate, the DoE performs a broad range of activities with limited staff and technical capacity (sections 3.5 and 3.6). Although water pollution is a serious problem in Bangladesh, especially from industrial waste and inadequate WASH, the DoE does not have a specialized unit directly focusing on water quality, and this function is partially covered by the NRM directorate because of its mandate over wetlands. Understaffing and lack of clear strategy for the new chemicals and waste management unit also hamper the control of lead and other heavy metals contamination. Although approved by the 4th meeting of the National Environment Committee in 2017, the establishment of a training and research center for environment and climate issues at the DoE is still under process (MoEFCC 2023).[26] A potential overlap results from the NRM directorate's oversight of ecologically critical areas management and biodiversity matters, while BFD also performs activities to "manage and conserve forest resources along with biodiversity and watershed management and development [... and] enforce laws and regulations for the protection and management of forest resources and wildlife as the custodian of the government forests." (BFD 2018).

Because of those shortcomings, before amending the ECA 1995 and setting clearer mandates for environmental governance, the GoB should proceed with a detailed analysis of the organizational structure under the MoEFCC and affiliated agencies. The analysis should identify gaps and overlaps in the institutional framework and recommend a restructuring process to address those deficiencies – either creating, removing or expanding units to increase efficiency across environmental agencies. For example, merging the NRM agenda and BFD's mandate under a single department could be an option. This new specialized agency would cover all matters of NRM, including (a) ECA management, (b) forests, (c) biodiversity and biosafety, (d) water ecosystem management, and (e) land degradation management. In parallel, the DoE would focus on pollution management and environmental health issues. The DoE would keep some NRM specialists for enforcement and environmental clearance activities. In any case, for the greater interest of the country's natural resources conservation and for its sustainable use, DoE and BFD must work together in their jurisdiction under the supervision of the MoEFCC.

3.4.2 Budget and human resources

Despite some improvements, the MoEFCC is still underfunded. The ministry's budget allocation was BDT 10.3 billion in fiscal year (FY) 2017, approximately $124 million and about 0.2 percent of the national budget. Since FY2020, when the country's revised budget prioritized interventions to address the impacts of the COVID-19 pandemic, the MoEFCC annual budget has increased gradually, reaching BDT 15 billion in FY2023, approximately $142 million and equivalent to 1.5 percent of the national budget (table 3.1). However, a significant portion of that increase came with development projects, and because of some delays in their implementation, the percentage of unspent budget reached 11 percent in FY2021.

Table 3.1 MoEFCC annual budget (per fiscal year) | *BDT, thousands*

Fiscal Year	Allocated Budget			Total Expenditure			Unspent Budget
	Management	Development	Total	Management	Development	Total	%
2018/19	82,034	52,008	13,4042	79,788	51,858	131,603	1.81
2019/20	54,841	34,334	89,175	50,455	33,906	84,362	5.39
2020/21	62,351	41,356	103,707	56,204	35,907	92,111	11.18
2021/22	67,109	55,269	122,378	63,910	47,101	111,011	9.23
2022/23	76,257	73,869	150,126			—	

Sources: MoEFCC 2023; MoF 2022.
Note: — = Not available.

Another challenge is ensuring the efficient use of resources and a more equitable distribution across the MoEFCC's departments and associated agencies. Within the MoEFCC, the current institutional setup, budget allocation and staff distribution indicate a strong focus on forest-related issues. BCS has a specific Forest cadre, providing more stability, specialization, and promotion opportunities for staff of forest-related agencies. There is no doubt that forests are extremely relevant to the country's sustainability, resilience and livelihoods. In 2015, the forest cover in Bangladesh was 1.88 million hectares or 14.1 percent of the country's land area, including approximately 1.2 million hectares owned by BFD (GoB 2020). However, the discrepancy in staff and budget allocation among the MoEFCC's departments is not consistent with Bangladesh's environmental priorities, as shown by the costs of environmental degradation (Chapter 2).

The DoE's annual budget accounts for 9.16 percent of the MoEFCC's budget, compared to 69.39 percent of BFD's budget. Although the DoE's annual budget has also increased in the past years, reaching BDT 1.37 billion in FY2023 (approximately $12.9 million), it is still insufficient to fulfill its multiple functions (table 3.2). While Bangladesh aspires to become a middle-income country, the DoE's approved headcount and budget are notably lower than that of environmental agencies of comparatively sized middle-income countries, where staffing data was available (table 3.3).[27] The BFD should provide the benchmark, and the DoE's budget and staff should be leveled up to those standards.

Table 3.2 Human resources and general budget allocation (FY2023) of MoEFCC's agencies

Department	Approved Posts	Workforce in Service	Vacant posts	Annual budget (BDT in thousand)	Share of MoEFCC annual budget (%)
Secretariat, MoEFCC	184	125	59	26,684.00	17.77
Department of Environment	1,133	580	553	13,755.52	9.16
Forest Department	10,492	6,989	3,503	104,178.00	69.39
Forest Research Institute	769	389	380	4,846.00	3.22
Bangladesh National Herbarium	52	40	12	662.48	0.44
Bangladesh Forest Industries Development Corporation (BFDC)	6,563	5,029	1,534	0	0
Bangladesh Climate Change Trust (BCCT)	82	58	24	0	0
Bangladesh Rubber Board (BRB)	70	17	53	0	0

Sources: MoEFCC 2023; MoF 2022.
Note: BFDC has its own budget as a state-owned enterprise. Since BCCT and BRB are included in the support budget category, they are not reflected in MoEFCC's general budget.

Table 3.3 Annual budget allocation and approved headcount in environmental agencies of selected countries

	Bangladesh (DoE)	Philippines (Environmental Management Bureau)	Mexico (SEMARNAT, PROFEPA, ASEA)
Country population (2022)	171,186,372	115,559,009	127,504,125
Country GDP ($) (2022)	460,200,000,000	404,280,000,000	1,410,000,000,000
Total approved agency (headcount)	1133	1772	9985
National population by employee, based on headcount	151,091	65,214	12,770
Environmental agency budget (FY2022) ($)	16,823,300	69,679,487	2,399,756,210
Environmental agency budget per capita	0.10	0.60	18.82
Environmental agency budget as share of national budget (percentage)	0.03	0.07	0.21

Sources: GoM 2023; GoPh 2023; Secretaria de Hacienda y Credito Publico 2022;
Note: In Mexico, data include aggregate budget for (i) the Ministry of Environment (SEMARNAT) for policy making; (ii) the Agency for Safety, Energy and Environment (ASEA), which approves environmental clearances and conducts environmental enforcement for the energy sector; and (iii) the Federal Attorney Office for Environmental Protection (PROFEPA), which oversees enforcement of environmental regulations.

Additionally, the sharp increase in the DoE's budget in fiscal 2019 and fiscal 2022 is associated with development expenditures (for example, public investment projects, which are one-time budget for specific purposes) rather than management expenditures (for example, recurrent expenditures for carrying out core functions, such as public officials' salaries, goods needed to provide services, social or economic interventions, and interest payments, among others) (table 3.4). In this context, the DoE must advocate for additional sources of revenue and identify ways to maximize resources allocated for environmental management. This could be done through market-based instruments (environmental taxes, pollution charges, service fees, green bonds, and so forth), earmarking of a portion of collected fines to environmental activities, partnerships with donors and the private sector, and the creation of a permanent Environment Fund. The latter could help the DoE mobilize sustainable financing for environmental conservation actions such as policy studies, research and development, technology pilots, and citizen engagement. Chapters 9 and 10 analyze policy options to maximize financing for environmental management.

Table 3.4 DoE annual budget (per fiscal year) | *BDT, thousands*

Fiscal year	Allocated budget			Total expenditure			Revenue collection
	Management	Development	Total	Management	Development	Total	
2018/19	420,000	1,049,200	1,469,200	352,213	988,260	1,340,473	700,592
2019/20	500,000	123,300	623,300	360,680	67,231	427,911	676,732
2020/21	523,330	261,400	784,730	412,569	191,190	603,759	769,401
2021/22	614,190	955,900	1,570,090	481,869	669,312	1,151,181	972,078
2022/23	692,552	683,000	1,375,552				—

Sources: DoE 2023; MoF 2022.
Note: — = Not available.

The rationale for budget allocation within the DoE is not clear either. Most financial and human resources seem to target the EC process, leaving even fewer funds for other key functions such as monitoring, enforcement, research, and policy making.

Even though the DoE has an approved headcount of 1,133 posts, it operated with 580 staff in FY2022, as bureaucratic delays have stymied hiring the rest of the staff. According to the DoE, in addition to the currently approved posts, the DoE needs an additional workforce of 3,259 staff to duly implement its mandate across the country (table 3.5). Staff shortage is particularly acute in the DoE's divisional and district offices, which typically have five to six staff and three staff, respectively. Instead of performing specialized activities and reporting to a thematic directorate, local staff are responsible for multiple functions, from processing environmental clearance files to carrying out remediation and enforcement actions. They are responsible for overseeing all industries and development activities that require compliance within their jurisdiction and nearby districts where the DoE does not have an office.

Table 3.5 Approved and hired staff in the Department of Environment (number)

<table>
<tr><th>Category</th><th>Approved staff</th><th>Employed staff</th><th>Vacant posts</th><th>Additional posts required</th></tr>
<tr><td>Officer Class 1</td><td>274</td><td rowspan="13">223</td><td rowspan="13">51</td><td>823</td></tr>
<tr><td>Director General</td><td>1</td><td>0</td></tr>
<tr><td>Additional Director General</td><td>1</td><td>0</td></tr>
<tr><td>Deputy Director General</td><td>0</td><td>2</td></tr>
<tr><td>Director</td><td>23</td><td>31</td></tr>
<tr><td>Deputy Director</td><td>58</td><td>198</td></tr>
<tr><td>Senior System Analyst</td><td>1</td><td>0</td></tr>
<tr><td>Environmental Magistrate
(Executive Magistrate)</td><td>8</td><td>12</td></tr>
<tr><td>Assistant Director</td><td>120</td><td>372</td></tr>
<tr><td>Senior Chemist</td><td>39</td><td>183</td></tr>
<tr><td>Research Officer</td><td>7</td><td>4</td></tr>
<tr><td>Accounts Officer</td><td>7</td><td>14</td></tr>
<tr><td>Librarian, Scientific Officer, Assistant Programmer, others</td><td>9</td><td>7</td></tr>
<tr><td>Officer Class 2
Inspectors, junior chemists, others</td><td>201</td><td>64</td><td>137</td><td>743</td></tr>
<tr><td>Supporting staff Class 3</td><td>428</td><td>204</td><td>224</td><td>1,215</td></tr>
<tr><td>Supporting staff Class 4</td><td>230</td><td>89</td><td>141</td><td>478</td></tr>
<tr><td>Total</td><td>1,133</td><td>580</td><td>553</td><td>3,259</td></tr>
</table>

Source: DoE 2023.

However, having a larger number of approved staff might not result in improvements in the DoE's performance if those positions remain vacant or are not filled by professionals with relevant technical backgrounds. The DoE's staff is mostly comprised of generalists from other cadres of the BCS, as there is currently no dedicated environment cadre. This lack of a specialized professional development path within the DoE serves as a disincentive for professional staff with relevant technical qualifications and expertise, leading to frequent turnover as they pursue opportunities in the private sector or other government agencies after hitting the internal "glass ceiling" (World Bank 2018). In this context, despite regularly recruiting staff, the DoE faces difficulty in retaining its experts and filling vacant positions.

The absence of an environmental cadre also has implications at the leadership level. In some cases, senior officials who are well-intentioned may lack the technical expertise to fully assess the implications of important decisions they make. In addition, members of the civil service cadre often reach these leadership positions when nearing retirement, which can also contribute to frequent turnover. This constant rotation of senior officials without a background in the field results in a continuous need for learning and adaptation, which also affects the DoE's performance. Staff shortage, coupled with weak technical capacity, has implications for the quality of the DoE's services and its capacity to monitor environmental quality and compliance with environmental standards. These limitations are particularly evident in the districts where the DoE lacks a physical presence, resulting in challenges in verifying all regulated entities (Iftekharuzzaman 2022).

3.4.3 Coordination across agencies and with local governments

Strengthening the MoEFCC's capacity to coordinate with and provide guidance to other ministries and agencies, such as the MoI and the MoC, in addressing environmental priorities is a pressing need. While most private industries are not under the direct control of the MoI, this ministry could contribute more to (a) improve the environmental performance of industries by promoting resource-efficient and cleaner production (RECP), (b) strengthen testing and standards on chemicals and other pollutants through BSTI; and (c) foster stronger environmental management systems in the public corporations it oversees in the chemical, sugar and food, steel, and vehicle sectors, as well as in the industrial estates for cottage industries that it manages (World Bank 2018). In addition, the MoEFCC and the MoC could enhance coordination to attract sustainable investment in export-oriented industries. The MoC's Export Policy (2021–2024) aims to improve the quality of export products, enhance quality control and certification systems to meet global standards, encourage the use of advanced, sustainable, and environmentally friendly technologies to ensure standards and compliance, foster the production of high-value export products, and promote excellence in fashion and design. The DoE, DGHS, and DIFE should better coordinate their efforts for policy formulation, on-site inspections, training, awareness campaigns and other activities related to environmental health, work conditions, and OHS.

Although the activities of other sector agencies can have significant impacts on environmental management, these agencies do not always prioritize environmental compliance and research and innovation in green technology. The MoEFCC also faces challenges in influencing the work of other line ministries that make decisions with profound environmental implications, such as setting fuel prices or environmental taxes (Ahmed 2017). Such limited capacity is associated both with political power asymmetries between government agencies and staff constraints at the MoEFCC and the DoE to provide technical support during such interactions. There have been instances when government institutions have requested the MoEFCC's and the DoE's support and have not received it because of technical capacity constraints. The recently established NCAPC is expected to address coordination shortcomings in AQM. Similar initiatives should be considered to enhance institutional coordination for other environmental priorities.

Coordination with key stakeholders is crucial for learning and improving environmental decision-making. Formally, progress in implementing environmental policies and programs is assessed by the establishment of steering committees with members from relevant ministries and line agencies. The routine review mechanisms of these committees comprise monthly coordination meetings, monthly Annual Development Program (ADP) progress review meetings (physical and financial), Implementation, Monitoring and Evaluation Division reviews, and development partners' mission reviews (for donor-funded programs). Independent reviews are also undertaken occasionally. However, review mechanisms lack a quantitative monitoring and evaluation framework, are not underpinned by comprehensive data on environmental conditions, have no participation of stakeholders other than government officials, and can be subject to political bias and influence (Ahmed 2017).

Vertical coordination is also critical for the successful decentralization of DoE's functions. Local interests tend to motivate faster environmental degradation and natural resource depletion. Thus, there are good reasons to advance the decentralization of environmental management responsibilities, including the capacity to respond more effectively to local challenges. Since environmental problems are typically felt locally, district offices are often in a better position to address environmental problems in a more efficient way. However, without proper supervision from the Head Office, coordination and relatively similar institutional capacities across the local offices, decentralization may lead to significant differences in environmental quality across regions.

In this context, the 8th Five-Year Plan (2021-25) (8FYP) mentions that the GoB will promote decentralization of environmental management based on international best practices (GED 2020). In this process, the DoE's Head Office has kept functions that cannot be successfully decentralized as failure to fulfill them would potentially harm the environment and the population, such as (a) mandate over transboundary issues; (b) coordination of regional, divisional, and district offices, including collaboration and sharing of good practices, and monitoring and evaluation of environmental programs that impact multiple regions; (c) processing environmental clearance applications for industries and projects that extend to two or more departments; and (d) research related to climate change, air pollution, biodiversity, or water issues that affect multiple subnational areas, as well as multiple countries.

In parallel, the DoE has empowered subnational offices with responsibilities in environmental clearance, monitoring, and enforcement. In the medium term, more responsibilities could be delegated to local offices. This would help promote and facilitate public participation to foster greater political and cultural representation and transparency in the environmental decision-making process. These efforts would also contribute to following up on local environmental concerns and disseminating relevant information to constituents and stakeholders. In that process, the DoE must also consider political economy dynamics, the nature of the most serious environmental problems, and the actual strengths and weaknesses of both public and private sector organizations at different geographic levels.

Decentralization should also involve local governments, as they hold a major responsibility in implementing environmental regulations approved by the MoEFCC. However, the absence of a clear role for and limited capacity of LGIs in environmental management is another major institutional weakness in responding to priority environmental challenges. Although the MoEFCC and its departments, especially the DoE, are mandated with policy formulation, environmental clearance, monitoring and enforcement, other important roles and responsibilities that contribute to urban sustainability and climate resilience have been decentralized to city-level institutions. Some of those roles are related to NRM, industrial planning, land use, zoning, and management, as well as the provision of municipal services like WSS and solid waste management (SWM).

However, Bangladesh remains among the most fiscally centralized countries in the world. LGIs account for only 7 percent of the country's expenditures and 1.6 percent of total government taxes in Bangladesh (GED 2020).[28] Transfers of resources from the central government to LGIs for the latter's discretionary use, in the form of block grants, are even more limited—about 12 percent of total expenditures by LGIs in Bangladesh.[29] In addition, until recently, transfers from the central to local governments had no clear criteria, frequently determined by the political affiliation of locally elected managers, rather than the actual needs of the local population or a clear prioritization process (GED 2020). For example, an analysis of climate change transfers found that, even though poorer populations in rural areas faced higher climate change risks, they had received a minor portion of funds allocated for climate change adaptation. About 82 percent of such funds had been allocated to City Corporations and Paurashavas, while Zilla Parishads had only received 18 percent of the allocated resources (Sharmin et al. 2017).

With the amount of transferred funds being unpredictable, particularly to cover discretionary expenditures of LGIs, adequate planning at the local level has been virtually impossible (GED 2020). Constraints in technical capacity for designing priority interventions, financial reporting, and public participation in decision-making also affect local planning systems. Consequently, those weak financing and planning systems have affected the delivery of basic services in Bangladesh and led to poor accountability of LGIs, especially City Corporations and Pourashavas (urban LGIs). To start addressing that, in February 2023, the MoLGRDC introduced a new requirement for block grant allocations to urban LGIs—that is, at least 10 percent of those transfers from the central government must be used for green and climate resilient (GCR) priority activities. Urban LGIs will have the discretion to select the specific GCR actions based on the list of GCR goals and priority interventions extracted from the 8FYP and as specified in the corresponding circular.[30] As the next steps, the MoLGRDC is developing technical standards and procedures for local planning, including channels for monitoring and evaluation and ongoing stakeholder engagement. By 2025, the MoLGRDC plans to expand the block grant system reform to further incentivize urban LGIs to invest in GCR interventions by introducing performance criteria linked to GCR spending for allocating overall block grants.

3.5 Monitoring and evidence-based planning

Despite evidence on the major categories of environmental degradation in Bangladesh (Chapter 2), those key environmental health and pollution issues have received insufficient attention in the high-level policies, instruments, and budget allocations of recent years. In the case of lead exposure and indoor air pollution, the GoB has yet to define clear policies and an institutional framework to tackle these issues, including clear responsibilities and timelines to tackle these risks. This misalignment between environmental priorities, institutional efforts, and resource allocation is largely due to (a) the absence of an integrated system of reliable data and organizational capabilities to provide analytical support to the decision-making process, (b) the lack of representation of vulnerable groups that are mainly affected by environmental degradation, and (c) the absence of a formal planning mechanism for allocating financial and human resources according to clearly defined environmental priorities that are linked to poverty alleviation and social priorities.

The DoE has limited capacity to conduct research, to properly monitor environmental quality and pollution discharges and, based on those findings, to inform policy formulation and environmental decision-making—for example to identify pollution hotspots and priority actions. Environmental monitoring capacity is constrained by various factors, including the absence of reliable time series data on the state of the environment and natural resources, the lack of a system of outcome-focused indicators of environmental quality, and insufficient resources to ensure an adequate institutional presence in the field—such as human resources, monitoring devices, laboratory facilities, and information systems.

Ambient air quality data collection has improved over time. The first full-fledged Continuous Air Monitoring Station (CAMS) under the DoE was set up in 2001. There are now 16 continuous air monitoring stations, complemented by 15 compact monitoring stations (DoE 2018; GED 2021). These monitoring stations measure concentrations of five criteria pollutants (particulate matter—$PM_{2.5}$ and PM_{10}, O_3, SO_2, NO_X, and CO)[31] every minute and transfer this data every 15 minutes to the DoE's central office, where they are stored. While the World Bank-funded "Clean Air and Sustainable Environment" (CASE) Project was operational (2009-19), it generated monthly air quality reports summarizing collected air quality data. After that, the DoE had not published air quality reports periodically. In November 2023, the DoE started disclosing the Air Quality Index in its website, to inform a wide audience about air quality and the recommended actions under different levels of air pollution. While recognizing the DoE's progress in establishing a network of reliable air quality monitoring stations, further strengthening is necessary to address the following challenges: (a) current number of existing stations is insufficient for the entire country, and difficulties persist in identifying suitable sites for additional stations within populated cities; (b) temporary shutdowns or defects in monitoring devices due to the lack of direct business presence of equipment manufacturers combined with inadequate procurement planning for spare parts; (c) absence of qualified local staff, complicating operation and maintenance of imported equipment; (d) power disruptions, affecting instrument stability and data integrity; (e) limited capacity to monitor emissions from stationary and mobile sources; and (f) need to enhance the AQI system for a more agile calculation and dissemination, using an user-friendly approach. Regarding water quality, the GoB has no continuous surface water quality monitoring stations to assess real-time water quality in Bangladesh rivers, targeted international rivers, and effluent treatment plants.

Challenges in the use of statistical methods used for sampling (for example, the uncertainty level associated with the sampling results) have also affected the validity and representativeness of the environmental data. As a result, the aggregate results of environmental quality data in air and watersheds are not always reliable and, therefore, of limited usefulness for environmental policy formulation. Poor analysis also hampers monitoring efforts, as third-party laboratories undertake most of the analysis of samples for industries and projects, and the authorities do not maintain rigorous quality control amongst the labs. Additionally, even when information exists, it cannot easily be shared across agencies involved in different aspects of environmental quality control, as the country lacks established norms for inter-operational processes to facilitate information exchange among the agencies.

The lack of outcome-focused monitoring and evaluation processes poses additional challenges in environmental planning. Although the MoEFCC must achieve annual targets under the 8FYP and, like the DoE, implement its commitments under the ADP, these planning instruments are not sufficient to fully assess institutional performance and improvements in environmental quality. ADPs are budget and output-oriented and do not set specific outcomes and results indicators. Although part of the 8FYP targets could measure outcomes, those indicators lack precision and focus mostly on outputs—such as approval of new regulations or broad activities that are not linked to specific targets (for example, "Develop more bilateral and multilateral engagements") (GED 2022).

The DoE also lacks a comprehensive information system to effectively manage monitoring and enforcement information, as well as handle environmental complaints from citizens. Regarding transparency, the DoE publishes an annual report of its activities and thematic studies and has used an information system to process ECCs. However, there are no systematic publications on environmental quality data in a user-friendly format to citizens or detailed information about its enforcement activities, such as industry names, types of violations and fines imposed during inspections.

BBS also faces constraints to gather, process and disseminate timely environmental data (appendix L). Specific challenges to implement the BESF include (a) lack of inter-ministerial and inter-agency coordination; (b) lack of a common format and platform for collecting, organizing and sharing environmental data; (c) absence of proper mechanisms to ensure the quality of data provided by respective responsible government agencies; (d) insufficient financial resources and inefficient methods for data collection, compilation, processing, and dissemination of environmental data; (e) absence of designated focal point officers in respective data providing government agencies; (f) shortage of skilled human resource capacity; (g) overly ambitious goals for data production that lack prioritization, among others.

3.6 Environmental enforcement

3.6.1 Mandates and regulations

Department of Environment. The ECA mandates the DoE to enforce environmental law in Bangladesh, especially the Act and its associated rules. Those enforcement powers include, among others, (a) searching any place, examining any equipment, manufacturing or other processes, ingredients, or substance for the purpose of improvement of the environment, and control and mitigation of pollution; (b) take samples of air, water, soil or other substance for analysis.; (c) collect, publicize and disseminate information regarding pollution; (d) order the closure, prohibition or regulation of any industry, undertakings, or processes; (e) seize any equipment, industrial plant, record, register, document, or other material that may be used as evidence of the commission of any offense punishable under the ECA or associated rules. The DoE can also confiscate materials and equipment involved in the offense, as well as cut off water, electricity, and other services from the offenders' facilities.

Mobile and Environmental courts. The Bangladesh Supreme Court, particularly the High Court Division, enforces environmental rights by exercising its constitutional power of judicial review, especially through writ petitions in public interest litigation. In addition, as per the ECtA 2010, specialized environmental courts receive and decide on judicial cases for violation of statutory environmental laws. These specialized courts can also intervene to protect people's constitutional right to a safe environment and balance the interests of multiple stakeholders, including future generations. The ECtA contemplates three types of environmental courts: (a) the Special Magistrate Court to adjudicate petty offenses, (b) the (Divisional) Environment Courts to decide on major violations, and (c) the Environment Appellate Court to hear appeals and review petitions in relation to decisions of the other two courts (Mulqueeny, Bonifacio, and Esperilla 2010, 288). Most special magistrates perform their duty in mobile courts, which are special courts that can move from one place to another, as needed to maintain law and order and to prevent offence immediately, by taking cognizance of offences immediately and giving prompt sanction (Mobile Court Act 2009). Expertise in environmental law is not a prerequisite, and any judge can be a member of environmental courts. In the case of mobile courts, the role of special magistrates can be performed by members of the executive branch. Although the ECtA aims to ensure the presence of at least one environment court in each district, it does not mandate their establishment as a separate or independent court. As a result, the GoB has established only four environmental courts to date, three district-level courts in Dhaka, Chittagong, and Sylhet, and an appellate court in Dhaka. Special magistrates can also conduct their judicial mandate at the DoE rather than in courts. In May 2023, there were five special magistrates performing their functions at the DoE (out of eight envisaged in the headcount), including the Director of the DoE's Monitoring and Enforcement Wing (MEW), who has also been appointed as a special magistrate.

The environmental courts' jurisdiction covers issues regulated by the ECA, other laws published in the government's gazette with explicit reference to such jurisdiction, and the rules made under these laws. Thus far, in addition to the ECA and ECR, environmental courts have considered only the BMBKEA as "other law published in the official gazette." The Act also bars individuals from directly filing suits to the court, thereby further limiting the courts' capacity to uphold environmental justice. Affected individuals must first file a complaint with the DoE. The DG will assign a DoE inspector to investigate such a claim and prepare a written report for the DG's review and decision on whether to take judicial action. However, the court may consider a direct claim from an individual if they had submitted a written report to the DoE, and after 60 days have elapsed since the submission, the DoE has not taken any investigative action. Even then, the court must offer the DoE adequate opportunity to rationalize its inaction.

Inspections. The DoE performs enforcement inspections through its MEW alone or in coordination with mobile courts. The wing has a mandate over the entire country and all matters under environmental law, such as effluent treatment and emissions limits from industries. In addition to regular inspections, the MEW acts when (a) district offices and laboratory offices find irregularities in environmental quality standards or in emissions and effluents limits in certain areas or specific industries or projects and (b) citizens complaint to the DoE about environmental noncompliance and damages. To conduct activities outside Dhaka, the MEW requires support from inspectors at district or divisional offices. In parallel, mobile courts have a mandate to inspect industries, projects, and individuals for compliance with environmental regulations on (a) polythene ban, (b) vehicle emissions standards, (c) brick kilns, and (d) construction materials. At mobile courts, the special magistrate may acknowledge an offense directly upon complaint by the DoE inspector or authorized officer without following further formalities. If the applicable penalty exceeds 5 (five) years of imprisonment or 5 (five) lac taka in fines, the special magistrate must refer the case to the Environment Court.

Penalties. Section 15 of the ECA sets forth penalties for violations of its provisions or for noncompliance with DG's directions (table 3.6). Only a Special Magistrate or Environmental Court can impose those penalties. In addition, ECA Section 15(2) states that rules under that Act can specify certain offenses and their corresponding penalties, although the sanctions so specified shall not exceed imprisonment for two years or a fine of Tk 2 lac or both, and there is no reference of increased fines in case of subsequent offenses. The ECR, EMR, SWMR, APCR, and BMBKEA set forth penalties based on those parameters.

The DoE does not receive a portion of the collected proceeds from environmental penalties, which are not earmarked to finance environmental management initiatives. Additionally, setting specific fine ranges through an act (law) has impeded the Government from regularly updating their value, as an amendment to a law requires years of drafting, consultations, and discussion at the Parliament. As per ECA Section 15 (last updated in 2010), the maximum fine amount is BDT 1,000,000 (equivalent to approximately $9,400), applicable in cases of subsequent offenses. Considering a depreciation of 56.76 percent in the BDT value between 2010–2023, the maximum fine should be updated to at least BDT 2,167,178 to keep its value.[32]

Table 3.6 Summary of applicable penalties per ECA Section 15

TYPE OF OFFENSE		APPLICABLE PENALTY	
ECA section	Noncompliance or violation of direction(s) regarding the following:	First offense	Each subsequent offense
Subsection (2) or (3) of section 4	Measures ordered by DG for the conservation of the environment, improvement of environmental standards, and the control and mitigation of environmental pollution. Directions may include closure, prohibition or regulation of any industry, undertakings, or processes.	Imprisonment minimum 1 year, not exceeding 2 years, or a fine minimum of 50 thousand taka, not exceeding 2 lac taka or both.	Imprisonment 2 years, not exceeding 10 years, or a fine of 2 lac taka, not exceeding 10 lac taka, or both.
Section 5, sub-sections (1) and (4)	Continuing activities or processes or initiating activities or processes are prohibited in ECA.	Imprisonment, not exceeding 2 years or a fine not exceeding 2 lac taka or both.	Imprisonment 2 years, not exceeding 10 years or a fine 2 lac taka, not exceeding 10 lac taka or both.
Section 6, sub-section (1)	Restrictions regarding vehicles emitting smoke injurious to the environment.	Fine not exceeding taka 5 thousand.	Second offense: fine not exceeding taka 10 (ten) thousand. Each subsequent offense: imprisonment not exceeding 1 year or a fine not exceeding taka 10 (ten) thousand or both.
Section 6A	(a) Manufacture, import, and marketing of polythene products. (b) Sell, exhibit for sell, storage, distribution, transport, or use for sale of polythene products.	(a) Imprisonment not exceeding 2 years or a fine not exceeding 2 lac taka or both. (b) Imprisonment 1 year or a fine not exceeding 50 thousand taka or both.	(a) Imprisonment for 2 years, not exceeding 10 years or a fine of 2 lac taka, not exceeding 10 lac taka or both. (b) N/A
Section 6B	Restriction on cutting hill.	Imprisonment not exceeding 2 years or a fine not exceeding 2 lac taka or both.	Imprisonment 2 years, not exceeding 10 years or a fine 2 lac taka, not exceeding 10 lac taka or both.
Section 6C	Restriction on production, import, storage, loading, transportation, and so forth of hazardous waste.		
Section 6D	Restriction on pollution due to ship breaking.		
Section 6E	Restriction on water reservoir.		
Section 7, Sub-section (1)	Compensation and remediation of any act or omission of a person that is causing or has caused, directly or indirectly, injury to the ecosystem or to a person or group of persons.	Imprisonment minimum 1 year, not exceeding 2 years or a fine minimum of 50 thousand taka, not exceeding 2 lac taka or both.	Imprisonment 2 years, not exceeding 10 years or a fine of 2 lac taka, not exceeding 10 lac taka or both.
Section 9, Sub-sections (1), (2), and (3)	Control, mitigate, and immediately report to DoE the discharge of environmental pollutants above the prescribed limits due to accidents or other incidents. Failure to adopt remediation measures as per DG direction.		
Section 10, sub-section (2)	Failure to render, without reasonable excuse, assistance, or cooperation to the DG or authorized person.	Imprisonment minimum 1 year, not exceeding 3 years or a fine of 50 thousand taka, not exceeding 3 lac taka or both.	N/A
Section 12	Environmental Clearance Certificate.	Imprisonment minimum 2 years, not exceeding 5 years or a fine of 1 lac taka, not exceeding 5 lac taka or both.	N/A
	Any other provision of the ECA, a direction issued under the rules, or obstructing the DG or authorized person in discharging his duties or intentionally delaying the discharge of such duty.	Imprisonment not exceeding 3 years or a fine not exceeding 5 lac taka or both.	N/A

Source: ECA 1995, as amended in 2000, 2002, and 2010.

3.6.2 Trends in enforcement activities

After the EC system, Bangladesh uses Command and Control (CAC) as its major environmental policy instrument. Although it is technically simple to impose regulations with specific fines for noncompliance, data from Bangladesh show significant problems in implementing those regulations, especially when enforcement authorities have limited capacity, and polluters do not have incentives to comply with the law. CAC policies are not feasible for all types of pollution sources—for example, it would be impossible to enforce a regulation banning the use of solid fuels for cooking, which is the major source of air pollution in Bangladesh (chapters 2 and 6).

Factors affecting low compliance with existing CAC instruments include the ad hoc application of the polluter pays principle, with low and/or arbitrary fines and sanctions that are not able to deter polluting activities. From 2010 to 2018, the DoE imposed 2,800 counts of fines on industries and projects. Textile and fabric industries accounted for 47 percent of noncompliance counts (followed by 17 percent in brick kilns) and 67 percent of collected fines among all types of industries. Most enforcement activities focused on violations that contributed to water pollution (54 percent of noncompliance instances) (Ahmed, Hasan, and Sarwar 2021). The same study found no difference in mean fines among the first, second and third instances of violations, revealing that the DoE did not impose higher fines in case of recidivism.

The number of DoE staff continues to be inconsistent with the increasing number of industries over the years, which limited enforcement activities. The MEW has only 14 officers in service at headquarters (out of 17 posts envisaged in headcount) dedicated to monitoring 40,000 industries across the country and receives limited support from local offices, which makes enforcement activities beyond city centers even more difficult. Divisional and district offices have 37 staff (out of 61 posts of headcount) to support monitoring and enforcement activities.

From July 2021 to June 2022, the DoE imposed sanctions on 2,157 individuals, institutions, industries, and projects (hereinafter "entities") involved in environmental pollution, illegal hill-cutting and filling of reservoirs, including damage to the environment and surroundings throughout Bangladesh. Still, considering the country's pollution rates, those enforcement activities are modest. In those operations, under ECA Section 7, the DoE imposed compensations for the environmental damages to a few entities, in the total amount of BDT 510 million, out of which it collected BDT 247.7 million, the highest collected amount since FY 2012/13 (table 3.7).

Table 3.7 Levy and recovery of compensation for environmental damage as per Section 7 of ECA

Fiscal year	Number of sanctioned entities	Imposed compensation (BDT)	Collected compensation (BDT)	Collected vs. imposed compensation (%)
2010/11	343	312,700,000	150,500,000	48.13
2011/12	503	499,000,000	363,900,000	72.93
2012/13	510	384,700,000	336,200,000	87.39
2013/14	395	438,500,000	212,200,000	48.39
2014/15	422	397,200,000	227,800,000	57.35
2015/16	398	286,600,000	112,300,000	39.18
2016/17	1,049	189,300,000	142,100,000	75.07
2017/18	571	192,300,000	114,700,000	59.65
2018/19	875	196,700,000	113,800,000	57.85
2019/20	1,313	584,900,000	141,300,000	24.16
2020/21	1,313	688,700,000	109,000,000	15.83
2021/22	2,157	510,700,000	247,700,000	48.50
Total	**9,859**	**4,681,300,000**	**2,271,500,000**	**48.52**

Source: DoE 2022

The low collection rates are also associated with loopholes in the system, such as polluters' appeals to courts. There are no requirements for alleged offenders to pre-deposit in a judicial account at least part of the imposed fine as a condition to file appeals.[33] The latter is also motivated by imprecise regulations and excessive discretion of environmental officers, which may lead to errors and arbitrary decisions. For example, there is no specific guideline for the installation and operation of effluent treatment plants, for vehicle emissions control, chemicals and hazardous waste management, among other relevant topics. The lack of information on the DoE's website on specific violations constitutes an additional driver for noncompliance with environmental law by impeding citizen-driven accountability.

In the calendar years 2021 and 2022, special magistrates conducted 1,979 mobile courts in collaboration with the DoE (tables 3.8 and 3.7). Although mobile courts are more effective than regular MEW inspections, they can only act on pollution cases related to the polythene ban, vehicle emissions, brick kilns and construction materials. Therefore, the number of enforcement actions is modest, considering approximately 40,000 industries and 578,151 vehicles in the country in 2022 (BRTA 2022). Industries and projects are typically inspected as part of the EC process when developers expect an on-site visit from the DoE and in some cases are previously informed about the date of such visit. As for vehicles, there is only one BRTA center conducting vehicle inspections using advanced equipment, and road inspections by mobile courts and police are limited to visual inspections to spot gross polluter vehicles.

Table 3.8 Enforcement activities by mobile courts in calendar years 2021 and 2022

Year	Number of mobile courts operated	Number of cases filed [a]	Penalties		
			Monetary penalty imposed (and collected)	Imprisonment	Other
2021	923	2,567	BDT 89,722,526	33 individuals	123 brick kilns halted operations. 125 tonnes of polyethene seized.
2022	1,056	3,109	BDT 97,028,227	2 individuals	56.2 tonnes polyethene seized.

Source: DoE.
Note: [a] Multiple cases can be filed in a single operation.

Table 3.9 Enforcement activities by mobile courts in fiscal 2022 (July 2021 – June 2022)

Pollution source / natural resource depletion	Mobile courts operated	Cases filed [a]	Penalties		
			Fines (BDT)	Imprisonment	Other
Polythene	148	377	3,481,200		119 tonnes of polythene granules and raw materials seized
Black smoke from vehicles	19	138	200,700		
Brick kilns	278	681	182,848,500		129 brick kilns closed
Cutting hills	15	21	1,035,000		
Filling water bodies	11	20	395,000		
Stone crusher	11	214	4,934,002		
Additional pollutants	91	207	6,375,104	One month imprisonment to 13 persons	2,000 kg of lead (Pb) seized Three power generators seized Utility connection discontinued in 22 factories
Air pollution by construction materials	52	173	1,756,000		
Noise pollution	96	483	616,500		29 vehicle horns
Saint Martin Island (ECA)	25	27	462,000		
Total	746	2,341	202,104,006		

Source: DoE 2023.
Note: [a] Multiple filed cases can be filed in a single operation.

Other challenges for enforcing CAC instruments refer to (a) the DoE's limited coordination with other public agencies and local governments, for example, for targeting enforcement to pollution hotspots and sharing information, facilities, and equipment; (b) limited staff at the DoE to prepare the documentation needed to file and participate in judicial cases; (c) bottlenecks at environmental courts and delays in judicial cases, especially appeals from project developers against sanctions, which hampers fine collection by the DoE. Political interests also interfere with stricter environmental enforcement in Bangladesh (Ferdous 2017; Iftekharuzzaman 2022).

Since ECtA's enactment, the DoE has filed very few cases in the existing environmental courts. From July 2018 to June 2022, the DoE filed 465 and 358 cases before the special magistrate courts and environmental courts, respectively (table 3.10). As a court order is a condition for imposing penalties under ECA Section 15, the number of individuals and industries being sanctioned for their environmental offenses is minimal. Additionally, since the DoE does not have enough staff to follow up on those cases after filing them, the Department does not know the results of judicial orders, such as the value of fines imposed by the court and their enforcement. With limited staff, the DoE's Law Wing focuses on cases at the high court, mostly related to appeals from brick kilns to rejected ECC applications.

As of September 2022, there were 590 and 934 pending cases in the special magistrate court and environmental courts, respectively. To overcome such backlog, environmental interest groups, including NGOs, have filed public interest litigations before the Supreme Court on environmental matters. As a result, as of September 2022, there were 1,325 pending cases of environmental nature in the High Court Division out of 2,028 writ petitions. The DoE has provided 1,033 compliance reports in those cases (DoE 2023).

Table 3.10 Cases filed by DoE, charge sheets or investigation reports issued in the environmental courts

Fiscal year	Special Magistrate Court		Environment Court	
	Filed cases	Investigation reports / charge sheets filed	Filed cases	Investigation reports / charge sheet filed
2018/19	86	48	34	35
2019/20	75	48	126	42
2020/21	71	50	150	145
2021/22	233	177	48	125
Total	**465**	**323**	**358**	**347**

Source: DoE.

A key driver to the limited number of cases filed in Bangladesh's environmental courts is the legal requirement for the DoE to formally support any claim presented to a court. Most individuals, but particularly those with limited resources, are unable to follow the lengthy procedure before the DoE and later at environmental courts. Coupled with the small sanctions that the court can impose even to those who have committed grave environmental offenses, the current institutional framework has contributed to cultivating a culture of impunity for polluters. Under these conditions, the courts are unable to perform their duty as independent and appropriate forums for resolving environmental disputes (Preston 2014, 368).

Under its current design, the ECtA can also give rise to a conflict of interest. For instance, the DoE itself may be allegedly responsible for violating provisions of the ECA. Even under such a scenario, the court requires a written report from a DoE official to formally consider the case. The current system is also inadequate to respond to situations where a powerful government agency or influential corporation is responsible for violations of ECA provisions. The DoE has never filed a civil or criminal case against another government department, even though there have been high-profile cases documenting such violations. These circumstances undermine trust in the courts and their legitimacy (Hasanat 2021).

The lack of specialized judges also undermines the courts' performance. The GoB can appoint nonspecialized judges and magistrates to environmental courts in addition to their general role in non-environmental cases. However, Bangladesh's courts already face constraints by a limited number of judges and magistrates, and increasing the requirements needed to serve in an environmental court may have the unintended consequence of leaving environmental courts without a judge (Rahman 2020). Although this analysis recommends extending the legal standing before environmental courts to all citizens, the GoB shall accompany this reform with adequate resources to avoid an additional backlog of judicial cases. An alternative could be to ensure, by amending the ECtA, that judges have access to external experts who can contribute knowledge and evidence on highly technical and scientific issues.

The ECtA does not contemplate the appointment of independent environmental experts to advise the courts, which rely only on the testimony of government staff as experts, despite the potential conflicts of interest mentioned above (Mia 2015). It is a good practice for environmental courts and tribunals around the world to allow for the participation of independent experts to help judges and other stakeholders understand complex scientific and technical issues. Environmental courts comprising a judge, an environmental expert, and experts in other fields (for example, economics) have been effective in crafting judicial rulings that balance the economic interests of enterprises and the environmental damages caused by them (Bjällås 2010, 180–83). In coordination with other agencies, the DoE could also issue manuals and support the training of magistrates on relevant environmental issues, such as impacts of pollution, parameters to determine a penalty based on the damage, capacity payment of the offender, and recidivism, among other topics.

The High Court has developed more confidence in the DoE's compensation calculation methodology and has increasingly approved the DoE's method of collecting compensation, even instructing it to calculate compensation on the court's behalf (World Bank 2018). However, the DoE still faces challenges to collect fines and compensation. Bangladesh lacks a modern, transparent, rule-based system for applying the polluter pays principle and increasing the effectiveness of oversight activities. Such a system, coupled with reforms in ECA and ECtA, automated monitoring and disclosure of enforcement data, could reduce errors and arbitrary decisions, providing legal certainty to business developers, incentives for complying with the legislation and decreasing appeals of such sanctions. Additionally, the GoB should explore other types of environmental policy instruments to ensure compliance with regulations, including through financial incentives to deter harmful practices such as pollution charges and green financing to businesses for adopting RECP (chapters 9 and 10).

3.7 Conclusions and recommendations

Bangladesh's legal and institutional framework for environmental management is evolving, as discussed throughout this chapter. There are, however, opportunities to further strengthen the country's environmental systems and ensure it performs fundamental functions and coordinated actions to address environmental degradation. The GoB is already working in those interventions. The Bangladesh Environmental Sustainability and Transformation (BEST) Project (2023-28) will finance activities to improve environmental governance and infrastructure, enable green financing for air pollution control, and pilot initiatives for vehicle emission control and e-waste management (appendix M).

3.7.1 Strengthening the legal framework

A comprehensive amendment to the ECA and ECtA is needed to address some of the present recommendations and ensure a transformative change towards greening the economy and ensuring sustainable development. The ECA amendment should (a) envisage other types of policy instruments (beyond command-and-control); (b) expand the DoE's enforcement mandate, particularly to impose sanctions without judicial cases and ensure an automatic formula for regularly increasing the maximum amount of fines; (c) envisage other sources of revenues for environmental management such as a permanent environment fund that can receive resources from the DoE's service fees and damage compensation and provide grants to environmental initiatives such as piloting of green technology; (d) set the foundations for further regulation of EPR, PES, LMO, among other environmental themes; (e) require SEA for policies, programs and plans; (f) improve mechanism for meaningful stakeholder engagement in environmental decision-making. Through the MoF, it is also essential to adopt market-based policies for pollution management (chapter 9).

To make the environment courts system more effective for holding polluters accountable, the ECtA amendment should (a) allow affected parties to file lawsuits directly in the court instead of having to go through the DoE, (b) facilitate the use of scientific and expert evidence to inform judicial rulings in environmental cases, (c) give courts a broader mandate covering all environmental policies and acts, and ultimately holding government agencies accountable for their constitutional responsibility for environmental protection and the preservation of natural resources, (d) requirement of a guarantee deposit from the alleged offender as a condition for appeals, and (e) imposition of daily fines for delay in implementing a judicial order—for example, when an industry refuses to comply with a court's decision that orders it halt polluting activities. To design this reform, it is essential to conduct an in-depth assessment of Bangladesh's legal and institutional framework, including a benchmarking exercise with international good practices on environmental justice. Additionally, such policy reforms should be accompanied by adequate resources to avoid additional backlog of judicial cases, including budget increase and infrastructure development.

3.7.2 Strengthening environmental institutions

The GoB should carry out a detailed analysis of the organizational structure under the MoEFCC and affiliated agencies to set clearer mandates and more efficient processes for environmental governance The DoE still needs specialized technical units to respond to identified environmental priorities, with the necessary human, technical and financial resources to fulfill their mandates. In this regard, key measures include establishing a cadre of environmental specialists and increasing the headcount at the DoE to ensure that qualified professionals can reach senior official positions, attract, and retain talented individuals, and ensure that decisions and policies are made by people with adequate background and experience. For the environmental court system, the establishment of an environmental prosecution agency (or specialized unit) that is independent of the DoE and shielded from political interference must also be considered to make environmental justice more effective. This new agency or specialized unit requires legal and environmental experts with the capacity to develop solid cases before the courts.

The GoB should allocate more resources to the MoEFCC and the DoE, including by setting additional sources of revenues and strategies to maximize resources allocated for environmental management, such as environmental fiscal instruments (taxes, charges, bonds, and so forth), partnerships with donors and the private sector, and the creation of a permanent Environment Fund.

The GoB should consider additional mechanisms to foster inter-agency coordination, including for data exchange and joint monitoring and enforcement actions. Major environmental health and pollution issues still lack the minimum coordination structure for defining priorities and action plans across relevant sectors, such as health, energy, transport, and water. Similar initiatives to the NCAPC should be considered to enhance institutional coordination for environmental priorities. Efforts to foster closer inter-agency coordination could also be based on quantifiable goals. The process of developing environmental performance could be closely tied to efforts requiring units from different organizations to set specific quantifiable goals in their action plans and to systematically monitor their progress toward those goals. Ideally, this performance evaluation system would measure direct impacts on environmental quality, such as reduction in waterborne diseases or in outdoor and indoor concentrations of $PM_{2.5}$. Disseminating such data and publicly disclosing them can create strong incentives for compliance with coordinated plans and for improved institutional performance.

Decentralization of environmental management is key to better balancing the needs and priorities of central government officials and politicians with local stakeholders. Completing the DoE's decentralization process is essential to expand its physical presence to all districts and ensure that each of them is adequately staffed to perform all the DoE's functions efficiently and effectively and avoid conflicts of interest between ECC approval and enforcement. International experience shows that decentralization is particularly convenient when participation in decision-making and implementation and monitoring by local stakeholders play a central role in ensuring quality outputs and effective results. However, given that Bangladesh is among the most centralized countries in the world, any efforts to transfer more powers and responsibilities to local governments would need to be carefully assessed. Such transfer of responsibilities would need to be complemented with the corresponding transfer of resources and technical support to build the capacity of local governments. Initially, local governments could be increasingly engaged in monitoring of environmental data, dissemination of information and awareness campaigns, stakeholder engagement, and identification and interventions to reduce pollution from local sources.

3.7.3 Using evidence for planning and decision-making

To increase its monitoring capacity with reliable time series data, the DoE needs to urgently expand its data collection and processing on environmental pollution, including ambient air and water quality, solid and water-related waste, hazardous waste, and emissions from industries. These improvements must include establishing more automated stations for a granular picture of environmental quality across the country and ensuring that existing stations operate reliably and interruptedly. The monitoring systems must be accompanied by a system of outcome-oriented indicators of environmental quality and an adequate institutional presence in the field, with sufficient and well-trained staff. The GoB should also address constraints in implementing the Bangladesh Environmental Statistics Framework by improving the capacity of BBS and relevant data-producing government departments so they can properly gather, process, and disseminate timely and quality environmental data (appendix L). Additionally, health policies are needed to gather and process community-level data on the health issues and prevention measures in pollution hotspots, such as on blood lead levels, and incidence of diseases associated with inadequate WASH and air pollution.

Another important step to strengthen environmental planning is to ensure that data collected through monitoring is used to identify environmental priorities, assess alternatives to address them and evaluate progress in achieving environmental goals. The cost of environmental degradation (Chapter 2) is an example of a methodological approach to identifying environmental priorities, while cost-benefit analyses (Chapter 5) and economic and distributional modeling (Chapter 7) could be an approach to prioritize interventions that are likely to benefit individuals and society the most. In coordination with other agencies (for example, BIDS, BBS and DGHS), the DoE's upcoming research and training center should conduct analytical work to provide robust foundations for (a) setting environmental priorities across sectors, (b) allocating budget in response to those priorities, and (c) designing adequate interventions to address those priorities through diversified policy instruments and investments (Chapter 9). For example, including criteria linked to environmental and climate change challenges, poverty reduction and shared prosperity in the GoB's budget allocation procedures would contribute to reducing discretionary, unpredictable, and politically motivated transfers, which, in turn, is a necessary condition to strengthen the role of local authorities in environmental management.

By establishing systematic baselines and the evaluation of its interventions, the GoB could (a) gauge progress in responding to environmental priorities (such as the ban of two-wheelers to control air pollution) or identify reasons for unsuccessful interventions (such as vehicle inspections); (b) incorporate the lessons from previous initiatives; and (c) adjust policies based on new developments in science and technology (for example, recent evidence showing that $PM_{2.5}$ and lead cause significant health effects even at low levels that were previously considered safe). For setting a baseline, Bangladesh's environmental management system would benefit from a comprehensive evaluation, covering the adequacy of the current organizational structure and the efficiency and efficacy of the EC system as the main environmental policy instrument, among other aspects. Formal evaluation and learning mechanisms should be incorporated in the short run into the management routines of the DoE. The information collected with these tools is crucial for building performance-based indicators, which allow organizations to set measurable goals, evaluate their achievements, and engage in the process of reforming and improving their practices. Performance-based indicators also have the potential to strengthen the environmental sector by enhancing transparency and accountability, as well as by demonstrating the social benefits of investing public resources in environmental protection.

In addition to allocating more resources and capacity-building to the MoEFCC, the GoB might consider adopting results-based agreements to improve effectiveness and efficiency in the use of public resources in all sectors, including the environment. This approach consists of the signing of results-based agreements between the MoF and the MoEFCC and its agencies, including the DoE. The MoF and the leading sectoral agencies monitor compliance with the agreement based on a small, clear set of critical standards, indicators and milestones. Budgetary disbursements are subject to a given degree of compliance, and allocations in the following budget cycle are decided according to the previous cycle's results.

3.7.4 Strengthening environmental enforcement

Gaps in environmental policies, weak enforcement, and deficient technical capacity have rendered Bangladesh's environmental management framework ineffective in reducing environmental degradation. Enforcement is selective and sporadic, neglecting some of the most polluting activities, such as lead exposure.

As for command-and-control, a comprehensive amendment to the ECA, ECtA, rules and guidelines are needed to make enforcement activities more efficient, including clear provisions to implement the polluters pay principles, such as more specific parameters for assessing damage and determining penalties and the expansion of the DoE's mandate for imposing sanctions without a judicial process. The GoB needs to ensure that the adoption of laws and rules is coupled with more specific regulatory instruments—for example, guidelines, manuals, and technical standards. The absence of such instruments opens doors to legal uncertainty, discretionary decisions, appeals for imposed sanctions, and potential acts of corruption.

In parallel, the GoB should modernize and expand the range of policy instruments beyond command-and-control and, more specifically, the EC system. The Government could use several policy options: (a) economic and market-based instruments, such as pollution charges, deposit-refund schemes, EPR, and final demand interventions; (b) litigation-based instruments, including liability legislation, and (c) information-based instruments, such as awareness campaigns and regular dissemination of environmental quality data and pollution loads, lists of highly polluting industries, and results of enforcement activities. Other key interventions refer to enabling access to green financing and awareness campaigns targeting polluting industries, as in many cases, developers do not improve their practices because of limited resources and knowledge.

Enforcement also requires ensuring that authorities have the resources, equipment, and expertise to comply with these standards or, alternatively, establishing a system of certified third parties that can perform these functions. In addition, to increase the DoE's staff and improve its infrastructure, the GoB should use information technology to improve enforcement. For example, the demand for on-site inspection centers could be reduced if the Government requires highly polluting industries to install automated monitoring devices on premises, such as in stacks and CETPs, to transfer data on a regular basis to a DoE-managed information system. The latter would allow remote oversight and facilitate data analysis and dissemination. Additionally, the management of air and water quality monitoring stations could be outsourced to academic institutions or private entities. The demand for vehicle inspection centers could also be supplied through public-private partnerships.

3.7.5 Improving stakeholder engagement

Responding to priority environmental challenges in Bangladesh calls for a more systematic effort to raise awareness of environmental issues. Ways to improve public information and promote transparency, accountability, and awareness include the publication of data in support of key environmental indicators (including pollution loads and environmental health statistics); wider use of public forums for air development initiatives, and broader and more detailed review and discussion of environmental management tools.[34] Mechanisms to disseminate information in a manner that is easily interpretable can allow communities to serve as informal regulators; such mechanisms also promote accountability on the part of those being regulated and help prevent and mitigate the health effects of pollution. In this context, the DoE should expand dissemination mechanisms, such as the Air Quality Index, to cover other environmental topics and make use of social media and smartphones as dissemination tools. The DoE should also publish progress reports and evaluations with quantitative information to provide a more systematic and evidence-based approach to complement citizens' observations. Stakeholder engagement, especially those who are most severely affected by environmental degradation, is a key aspect to be improved in the EC process and, in the future, in SEAs (chapter 4). These stakeholder consultations are important to open environmental decision-making to public scrutiny and create opportunities for learning and evaluation, at both project and policy formulation levels.

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[24] These standards are (a) BDS 1423:2018 on enamel, synthetic, and exterior paints for undercoating and finishing applications; (b) BDS 1827:2018 on emulsion paints; and (c) BDS 1833:2018 on economy emulsion paints or distempers. These paints are commonly used in household and home decorations.

[25] The policy also bans the import of horns above 100 decibels to prevent noise pollution.

[26] The BEST Project will finance the establishment of the training and research center.

[27] Data constraints on the budget of environmental agencies, different methodologies or categories used by different countries in their public reporting, as well as specific country contexts and institutional structures for environmental agencies limited direct international comparisons. However, some comparisons were possible with Mexico and the Philippines, two middle-size countries where budget and staffing data were available.

[28] Analysis by the General Economics Division (GED) considered data from 16 developing countries and 26 developed countries. Spending by local government institutions represents 19 percent of total government spending in developing countries and 28 percent in industrial countries. Subnational government taxes account for 11.4 percent of total taxes in a sample of 16 developing countries and 22.7 percent in a sample of 24 industrial countries, compared with 1.6 percent of total government taxes in Bangladesh (GED 2020).

[29] About two-thirds of funding of LGIs comes from transfers from the central government, which are not for LGIs' discretionary use, such as special grants and project grants that are earmarked for the spending priorities of the central ministries that provide the funding.

[30] GCR priorities listed in the block grants circulars cover, among other, policies for green affordable housing, water, and waste management. Other examples of GCR priorities are (a) development of climate-resilient and flood-resistant infrastructure; (b) reduction of pollution; (c) proper drainage and sewerage systems; (d) increasing access to safe water, sanitation, and hygiene; (e) enhanced use of energy-efficient appliances in the official, residential, and commercial buildings; (f) solid waste management; and (g) environmental and ecological restoration and protection of forest and water bodies. MoLGRDC, Government Circulars dated February 9, 2023.

[31] Lead is also considered a criteria pollutant by the ECR, but it is not measured.

[32] The inflation calculation for Bangladesh is available at https://www.worlddata.info/asia/bangladesh/inflation-rates.php. Since inflation rates after 2022 are not yet available; consequently, for the following years, the last available rate of 7.70 percent was used in the calculator.

[33] This deposit would be kept in a special account and, after the court's decision, (a) returned to the appellant if he wins the case or (b) used to pay the fine and compensation, as applicable.

[34] In Colombia and Indonesia, among other countries, the publication of key environmental performance indicators has been instrumental in raising environmental awareness and placing environmental issues on the national agenda (World Bank 2005).

CHAPTER 4. ENVIRONMENTAL PLANNING AND ENVIRONMENTAL IMPACT ASSESSMENT

4.1 Introduction

Bangladesh has adopted the environmental clearance certificate (ECC) as the most common environmental management instrument to control environmental degradation from industrial units and projects (hereinafter "projects"). The environmental clearance (EC) process is centered on environmental impact assessment (EIA), covering both site and environmental clearance stages. Because of its nature, EC instruments in Bangladesh aim to manage the environmental impacts of specific projects rather than serving as a planning tool—based on participatory efforts to discuss the environmental and social concerns of different stakeholders—for governmental agencies' decision-making. As discussed in chapter 3, because of gaps in environmental regulations and prioritization of command-and-control policies, Bangladesh has used the ECC as a de facto substitute for more detailed environmental regulations and effective enforcement. Despite recent improvements with Environment Conservation Rules (ECR) 2023, the Government of Bangladesh (GoB) is yet to enhance the effectiveness of its EC system, taking advantage of this process to open environmental decision-making to public scrutiny and focus on concrete actions to improve the project's environmental performance—rather than just meeting pro forma legal requirements.

4.2 Objectives and nature of environmental clearance

The ECR defines the environmental impact assessment (EIA) as a well-organized process of identifying, predicting, and evaluating the potential environmental impacts of a proposed project or activity. As in other South Asian countries, the EIA tool (or the ECC in general) has two main objectives: (a) to avoid, minimize, or compensate for the adverse significant biophysical, social, and other relevant effects of development proposals; and (b) to protect the capacity of natural systems and the ecological processes to maintain their functions (Lima et al. 2015).

For the EC, Bangladesh's legislation recognizes only two types of environmental assessments: Initial Environmental Examination (IEE) and EIA. With no provision for Strategic Environmental Assessments (SEAs), the Bangladeshi EIA system does not extend to legislative processes, policies, plans, and programs, highlighting the fact that the EIA system is designed to address the impacts of actual physical activities on the ground. Projects with a minor impact on the environment, including on potentially affected people, are not required to obtain a site clearance but must apply to the DoE for an ECC. All projects with the potential to cause moderate to substantial environmental or social impacts must obtain both a site clearance and an ECC from the DoE to start operating. In those cases, land development, construction of any kind of infrastructure, and provision of basic utilities cannot be started without a site clearance.

The site clearance aims to ensure that projects (a) are not developed in sensitive areas (for example, protected areas, heritage sites, ecologically critical areas, habitats of threatened species, and declared forestland, among others); and (b) will be sited in an area with adequate environmental infrastructure to manage their effluents and waste.[35] The new ECR requires that DoE staff visit the project site before approving the site clearance and again before issuing the environmental clearance. With this new requirement, the DoE will need even more resources to fulfill its mandates and ensure quality and efficiency in the clearance process.

The DoE is responsible for implementing the EIA system, performing functions such as (a) issuing guidelines on how to conduct EIAs for specific projects or sectors; (b) administering the site-clearance processes and ECC processes; (c) reviewing the site-clearance applications and ECC applications, including the project's potential environmental and social impacts and the proposed mitigation measures to avoid, prevent, or mitigate those effects; (d) deciding on the site clearance and ECC application considering the project's expected residual impacts (that is, those likely to occur after the implementation of mitigation measures); and (e) when applicable, renewing ECCs. The DoE also coordinates with other public agencies (such as the Bangladesh Forest Department and the Ministry of Industries) that may oversee other aspects of the project's development and operations.

In line with the DoE's decentralization process, the ECR 2023 gives more responsibility to local offices—which were not mentioned in the ECR 1997—and establishes the designated office (district, divisional, metropolitan, regional, or head offices) responsible for receiving the ECC applications, which must be submitted online by default.

4.3 Screening

The requirements and procedures of the ECC will depend on the project category: projects that may cause significant impacts require an environmental impact assessment (EIA), and projects with moderate or minor impacts are subject to simpler requirements. Through a screening process, the DoE determines the categorization of projects based on their potential environmental impacts: Green (minor), Yellow (moderate), Orange (considerable), and Red (severe). The categorization will define whether the project proposal should be subject to an environmental assessment and other requirements, the level of detail of such assessment, who will be responsible for reviewing the site and environmental clearance application, and the certificate validity, as detailed in table 4.1. The new rules also refer to social issues as part of the site and environmental clearance processes, an aspect that was not explicitly covered in the previous ECR.

The ECR 2023 has improved the screening process by updating and detailing the list of pre-categorized projects. For example, in the ECR 1997, all types of power plants were considered under the Red category, requiring a full EIA and yearly renewal. The ECR 2023 categorizes power plants by source of energy (coal, solar, waste, hydro, and so forth) and generation capacity. The new ECR also mandated the DG to decide on the categorization of non-listed projects, as well as to change the category for a project that is likely to cause more severe environmental impacts than those corresponding to its category.

Table 4.1 Summary of project categories

Potential environmental and social impacts	Requirements to apply for an ECC	Competent authority for deciding on ECC application	ECC validity
Category: Green			
Minor. Some mitigation measures may still be needed.	Submission of Form 3 of the ECR, with general information and description of raw materials and finished products. No application processing fee. The developer pays only the ECC fee based on the project investment amount.	Relevant DoE office (district, metropolitan, divisional, or regional).	5 years
Category: Yellow (formerly Orange A)			
Moderate. Mitigation measures can help to avoid environmental and social impacts.	Must obtain both site and environmental clearances. Submission of Form 3 of the ECR, with general information and description of raw materials and finished products. Process flow diagram, layout plan, and effluent-disposal system (as applicable). Payment of a clearance application processing fee of BDT 2,000 and ECC fee based on the project investment amount.	Relevant DoE office (district, metropolitan, divisional, or regional).	2 years
Category: Orange (formerly Orange B)			
Considerable. Appropriate mitigation measures are required to reduce environmental and social impacts.	Must obtain both site and environmental clearances. Submission of Form 3 of the ECR, with general information and description of raw materials and finished products. process flow diagram, layout plan, and effluent-disposal system (as applicable). Feasibility report and IEE. Environmental Management Plan (EMP), and additional plans on pollution minimization, occupation health and safety (OHS), solid-waste management, management of hazardous medical waste (as applicable), and relocation plan (if required). For industrial units or projects listed in Serial No. 63-113 of the Orange Category, the Environmental Clearance Committee (EC Committee) of the Head Office may require, based on the IEE and after endorsement by the DG, the proponent to conduct a full EIA if the potential impacts of the proposed industrial unit or project may cause severe impacts on the environment and human health. Payment of a clearance application processing fee of BDT 5,000 and ECC fee based on the project investment amount.	EC Committee of Regional, Divisional or Metropolitan Office for industrial units or projects listed in Serial No. 1-62 of the Orange Category. EC Committee of the Head Office for industrial units or projects listed in Serial No. 63-113 of the Orange Category that do not require a full EIA. DG, based on recommendation of the EC Committee of the Head Office for industrial units or projects listed in Serial No. 63-113 of the Orange Category that require a full EIA.	1 year

Potential environmental and social impacts	Requirements to apply for an ECC	Competent authority for deciding on ECC application	ECC validity
Category: Red			
Severe. Significant mitigation measures are required to reduce the environmental and social impact.	Must obtain both site and environmental clearances. Submission of Form 3 of the ECR, with general information and description of raw materials and finished products. Process flow diagram, layout plan, and effluent-disposal system (as applicable). ToR for EIA to be approved by the DoE. Full EIA to be completed before site clearance including EMP, and additional plans on pollution minimization, OHS, solid-waste management, management of hazardous medical waste (as applicable), and relocation plan (if required). EIA to be finalized after public consultation and the final version to be publicly disclosed. After site clearance and compliance with recommendations of the EIA, the ECC would be issued. Payment of a clearance application processing fee of BDT 10,000 and ECC fee based on the project investment amount.	DG, based on the recommendation of the EC Committee of the Head Office.	1 year

Source: ECR 2023.
Note: Three different versions of Form 3 are used to apply for an EC: (a) for industrial establishments, (b) for infrastructure projects, and (c) for healthcare institutions. In addition to the application processing fee, the developer must pay an additional fee for obtaining the site or environmental clearance (or its renewal) ranging from BDT 3,000 to 1,500,000, depending on the amount invested in the project. For all projects, the renewal fee is one fourth of the clearance fee. Brickyards have a different fee structure.

Although the ECR 2023 improved the screening process, the use of category lists as screening devices still presents challenges and may lead to ineffective and inefficient screening processes. By using rigid lists, a wide range of actions must be completed such as on-site inspections for all project categories, and the DoE does not have the ability to filter out those that would not generate significant environmental effects in particular projects. Schedule 14 lists screening criteria for projects that are not on the list. This appears to be a more rational approach and should be used instead of a list-based approach for all projects. However, the criteria currently proposed in ECR 2023 are very limited—focusing on pollution issues only—and should cover other important environmental and social parameters.

The value of issuing and renewing ECC for green and even some yellow projects is questionable. Those projects are not expected to cause significant environmental impacts, yet they require the DoE to devote its limited resources to conduct on-site visits (which has limited enforcement efficacy, since project proponents are expecting those inspections) and review applications for these projects. In recent years, the DoE received few applications for Green projects. This suggests that most of these projects are developed and operated without an ECC (section 4.8). In the ECA amendment and further ECR revision, the GoB should consider exempting these projects from the ECC process and instead focus on regulating them through other instruments such as technical standards for specific activities or land-use zoning. By reducing the number of projects that are subject to an ECC, the DoE would transfer valuable resources to enhance its enforcement capacity, invest in research for green technology, and promote transparency and public participation in decision-making.

4.4 Scoping and preparation of EIA

In Bangladesh, the EIA scoping is conducted by the EC Committee based on draft terms of reference (TORs) prepared by the project owner. The ECR set forth a set of information that project proponents must consider when formulating the EIA scope, including project alternatives, description of existing environment, potential impacts, and mitigation measures. The rules do not establish criteria for the EC Committee to distinguish between significant and nonsignificant project impacts and, based on that, decide on the proposed TORs. However, the DoE's EIA Guidelines for Industries 2021 describe the steps and possible techniques to be adopted by the developer in the scoping process, mentioning stakeholder consultations as a good practice.

To ensure that projects with very similar characteristics end up with similar EIA-related requirements, the GoB might consider developing more detailed, mandatory guidelines, but also requiring stakeholder participation in the scoping process—as suggested in the EIA Guidelines for Industres 2021, but not envisaged in the ECR 2023. Such participatory processes give an opportunity to potentially affected groups to express their concerns at an early stage and to ensure that the EIA duly considers the impacts that are the most significant to these groups. This would increase the effectiveness and efficiency of the EIA process by enabling the DoE, the project developer, and the rest of the stakeholders to focus on the most significant issues associated with the proposed project.

Regarding the EIA preparation, project owners are responsible for hiring consultants registered with the DoE to conduct the necessary assessments. Environmental consultants and thematic experts must have a postgraduate degree in a relevant field and at least five years of experience preparing EIAs. As per the ECR 2023, consultants shall act independently and impartially in the EIA preparation, in consultation with all concerned parties and following the guidelines under its Schedule 11 for the EIA Report and Environmental Management Plan (EMP). Consultants shall agree with the project owner for formulating the EMP and the monitoring program.

However, there is a clear conflict of interests that may affect consultants' independence. Some developers, who will ultimately pay the consultants, are mainly concerned with obtaining the ECC as quickly as possible and not in conducting a rigorous evaluation or meaningfully engaging stakeholders. Therefore, the project developer has incentives to hire a consultant that only focuses on meeting the minimum legal requirements set by the authority and overcoming any potential objections to the project. Since consultants are selected and referenced by developers, they lack incentives to include in their documents information that may be relevant for the authority, if such information may result in denial of the ECC or the setting of additional conditions for the approval of the proposed project. The effects on the EIA's quality may also be exacerbated by the new deadlines for the DoE to approve the ToRs and the ECCs. With a massive workload and the pressure to comply with deadlines, DoE staff may limit the EIA review to the documentation prepared by the consultants, without asking for additional information to complement the EIA.

In addition, the EIA should be prepared following the sector-specific guidelines approved by the DoE and, in their absence, those developed by international organizations. The EIA Guidelines for Industries 2021 remain the only available document issued by the DoE with detailed information on how to conduct an EIA. The DoE revised these guidelines in 2021 to incorporate aspects of OHS and cultural heritage sites, though a new revision is required to incorporate provisions from the ECR 2023. The lack of guidelines for non-industry projects has resulted in confusion and ad hoc application of environmental requirements for developers requesting an ECC (Ahammed and Harvey 2004). In the short term, the DoE needs to (a) revise the EIA Guidelines for Industries, updating and expanding their contents as per the ECR 2023 as applicable; and (b) in collaboration with relevant agencies, develop guidelines for non-industry projects, preferably by sector, which could be based on guidance instruments issued by international organizations. Those guidelines should be legally binding.

4.5 Consultation and public participation

The involvement of different stakeholders in the preparation of the EIA, particularly the groups likely to be affected by the development of a project, is crucial to ensure the legitimacy and credibility of the EIA and the associated decision-making process. Public participation within the EIA process has multiple objectives, ranging from gathering data and information from the public about their human and biophysical environment, to seeking public input to identify potential impacts and mitigation or compensation mechanisms, to enhancing the quality of the decision-making process and increasing public acceptance and support for the proposed action (André et al. 2006).

The ECR 2023 has introduced general provisions on public participation, such as requiring the developer to consult the public in the project area by both organizing public hearings and providing opportunities to stakeholders to submit their written comments. While this change represents important progress compared to the ECR 1997, stakeholder consultations in the environmental clearance process are still limited, since they are required "in applicable cases," only for Red category projects, and after the scoping stage. There is no definition of "applicable cases" in the ECR. The scope of consultations will be local, regional, or national, depending on the geographic extent of the project. The developer is responsible for making a draft EIA and its Bangla summary available to the public on its website and at the concerned DoE office and website. The developer must also publish a notice with the date and time of the public hearing in a widely circulated local and national newspaper, and the same information must be posted on the websites of the DoE and the project proponent. The public can comment on the draft EIA online within 30 days of its publication. The minutes of the public hearing must be approved by the concerned DoE office and attached to the EIA report. The proponent must incorporate the necessary changes to the EIA report and EMP in the light of public consultations. Notwithstanding, the ECR does not require the developer to justify when comments are not incorporated in those instruments. The approved EIA report must be uploaded on the DoE website for public information. The ECR does not mention public disclosure of other relevant documents such as the IEE for Orange projects, the minutes of the EC Committee, the EMP, or even a list of projects that have received an ECC.

Without further regulations, public consultations can end up being geared more towards dissemination of project information rather than providing a mechanism whereby public comment and input can enter the decision-making process and affect the outcome of approval decisions (Acerbi et al. 2014; Lima et al. 2015). In addition, public hearings are often resource intensive and, if not properly organized, can easily turn into a community's opportunity to voice demands for issues with little or no relationship to the project. Limited provisions for disclosure of information beyond the EIA report also affect transparency and accountability. Based on that, when revising ECA in the next years and then amending the ECR as the new act, the DoE should consider the following steps: (a) expanding the requirements of stakeholder consultations and access to information to other project categories and pertinent documents, and (b) detailing those procedures through guidelines. These new requirements should be accompanied by adequate resources for the DoE and increased awareness of relevant stakeholders.

4.6 EIA review

For projects requiring a full EIA, the project proponent shall attach the necessary documents to the application, including a draft ToR for the EIA. A DoE official is responsible for conducting an on-site inspection and then forwarding the application to the headquarters with recommendations for granting a site clearance or rejecting the application. Although the ECR describes the information needed from the project proponent, it does not describe the criteria to support the decision on the ECC application. The official's opinion is submitted to the EC Committee, which is responsible for evaluating the EIA report. To receive the committee's approval, the EIA must adequately measure the project's environmental and social impacts; include an EMP and a monitoring program that are reasonable, effective, realistic, and adequate; and ensure that the project is not contrary to government policies and plans. The committee must consider the comments received during public consultations. Based on this information, the committee will recommend to the DG if the site clearance should be issued and if additional conditions should be included in the approval. The proponent may be invited to the meeting of the EC Committee to clarify information on the EIA report. The EC Committee may also seek the opinion of other relevant agencies. Subsequently, upon compliance with the recommendations of the EIA, the ECC would be issued in favor of the project for one year subject to renewal after expiry.

The ECR 2023 also indicates that the EC committee must consider project alternatives when reviewing EIAs. As per the guidelines for scoping and preparing the EIA report, the proponent must provide an "overview of alternatives, selection of acceptable options and rationale for discarding other options." It is not clear in the ECR whether the EC Committee can evaluate the "no project" option—although it could simply reject the ECC application—or consider an alternative that is different from the one selected by the developer, if there is a strong evidence base for promoting it.

As in many other countries, the Bangladesh regulations give significant discretion to environmental authorities to evaluate EIAs and decide on the ECC application. Although the ECR detailed the required information for each step of the ECC process, the regulations do not provide many criteria to substantiate review and decision-making. Thus, the DoE should adopt detailed guidelines on the issues that need to be highlighted in the minutes of the EC Committee and other relevant decisions. Those issues include what specific decision was made (for example, allowing a project to start land development and construction right after the site clearance and in parallel of EIA); what alternatives were considered by the committee and the environmental, technical, and economic considerations of each alternative and the way in which these were balanced in the decision-making process; and whether all practicable means to avoid or minimize environmental harm from the selected alternative have been adopted or the reasons for not adopting them. The DoE should also require the public disclosure of those minutes.

4.7 Follow-up of ECC conditions

Most EIA systems worldwide include a follow-up mechanism that helps authorities to ensure that the conditions included in the ECC are fulfilled, to monitor whether the environmental impacts are consistent with those predicted by the EIA, to assess whether the selected mitigation measures are effective, and to generate information to improve other EIAs.

According to the ECR 2023, the developer must include in the EIA a program to monitor the implementation of the mitigation measures, other indicators such as compliance with applicable environmental standards, and information on the team and budget dedicated to the program. As in other countries, EMPs are often used as remedies for the lack of legally established environmental standards or formal government programs. For example, some mitigation measures and other conditions included in the EMPs often include actions that are not necessarily related to the impacts that the project is expected to generate. Instead, some measures and conditions relate to activities (such as reforestation or education) that are socially desirable but that the authority is unable to carry out because of its constrained resources.

The ECR does not specify requirements on periodicity of monitoring reports from the proponent to the DoE. The most important follow-up mechanism remains the ECC renewal, for which the relevant DoE office must pay a site visit. At this stage, DoE officials are required to assess whether the project developer has met all the conditions included in the site and environmental clearances. The efficiency of this follow-up system is questionable. On-site inspection for ECC renewal has limited efficacy in environmental compliance because they are expected by the proponent, are unmanageable by the DoE limited workforce, and increase opportunities for rent-seeking behavior.[36] For example, as part of their EMPs, 172 industrial units have installed effluent-treatment plants (ETPs) in fiscal 2021/22, and the DoE has also approved Zero Discharge Plans proposed by 160 institutions. As of June 2022, the total number of industrial units with ETP was at 2,312 (MoEFCC 2023). However, the share of industries that operate the ETP on a regular basis is not clear since the DoE inspects most of them only through the site visits during the ECC process.

There is also a significant discrepancy between the number of projects expected to apply for an ECC annual renewal and those that applied for it (Section 4.8). This may occur because of the DoE's limited capacity to track, monitor, and follow up on ECC renewals, as well as limited understanding by ECC holders about their obligation to renew their clearances.

All these factors point to the need to adopt automated systems that can help the DoE to manage the ECC process. To address that, the DoE has introduced automation software (ecc.DoE.gov.bd) to process and track the ECC and renewal applications of any industrial factories or projects. This software has enabled the DoE to track the expiration of ECCs and which industries and projects must apply for an ECC renewal. However, this website should be made easily accessible to the public and expanded to cover the ECC's monitoring activities. In its current design, the website requires specific information in the search tool, such as the project or industry name or file number, to allow the public to search the status and relevant documents of an ECC application. To fulfill the disclosure requirements of the ECR 2023, the DoE must update the website design to make it more accessible to any citizen interested in various information, such as the ongoing projects in particular districts or thana and the totality of projects of a particular company in Bangladesh, as well as downloading relevant documents of specific ECCs. Additionally, the DoE should replace field visits for the renewal of environmental clearances with more efficient oversight instruments, particularly for green and yellow projects, and redirect the human and financial resources used in those activities towards enhanced enforcement activities.

To strengthen the ECC system, especially in the context of amending the ECA, the GoB should conduct an in-depth analysis of the conditions that have been included in ECCs for a wide variety of Red and Orange category projects and assess their effectiveness and efficiency in mitigating the project's impacts. Results of this analysis would be crucial to inform the ECA amendment and next ECR revision.

Another alternative that the GoB might consider consists of using a third-party system to conduct the monitoring of environmental and social indicators for high-risk projects. Under this system, the project developer or operators must cover the costs of such activities, but the funds are deposited in a government account. The DoE must then select the individuals or organizations that will conduct the monitoring from its registry and finance their services partially with fees collected from proponents during the ECC process. Additional mechanisms can help to reduce incentives for rent-seeking behavior. Such mechanisms include using software to randomly select the consultants that will carry out the work or restricting the number of years during which the same individuals can provide this service for the company

4.8 Trends in ECC applications and renewals

The annual average of ECCs issued for projects with moderate to significant impacts (Orange and Red category projects) was more than 5,400 between 2015–2022 (as per 1997 ECR). The lower number of ECCs in 2020 and 2021 may be attributed to the economic slowdown associated with the COVID-19 pandemic. In 2022, the number of granted ECCs increased to 5,566. Even though under the ECR 1997 the ECCs of those project categories needed to be renewed annually, historical data show large variation in the number of ECCs that were renewed in that same period, ranging from 9,992 in 2015 to 14,759 in 2022 (table 4.2). For example, the DoE issued 38,242 ECCs for projects of Orange A, Orange B, and Red categories between 2015 and 2021, which required the entrepreneur to renew the certificates within one year. However, the DoE renewed only 14,759 ECCs in 2022. Even if part of those industry units and projects went out of business, the proportion is still low considering ongoing projects with their first ECC approved in or after 2015, as well as the ECC renewal of Green category projects that were required every three years under the ECR 1997.

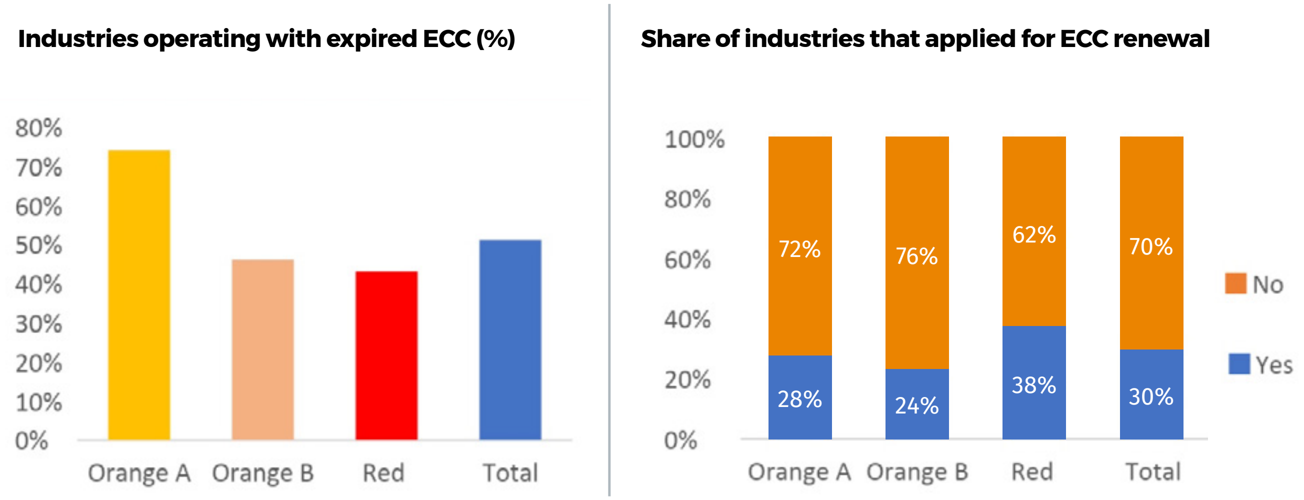
Table 4.2 Approved and Renewed ECCs in Bangladesh, 2015–22

Year	New ECCs					Renewed ECCs
	Red	Orange-B	Orange-A	Green	Total	
2015	399	3,123	2,726	16	6,264	9,992
2016	538	3,568	2,961	16	7,083	9,577
2017	681	3,731	2,450	25	6,887	10,451
2018	526	3,319	2,259	142	6,246	11,007
2019	613	3,322	1,263	117	5,315	11,778
2020	485	2,229	779	286	3,779	12,975
2021	564	1,969	737	263	3,533	12,076
2022	643	2,643	2,048	216	5,566	14,759

Source: http://DoE.portal.gov.bd/sites/default/files/files/DoE.portal.gov.bd/page/00bebf37_3b1e_4cde_b2d9_0eb26b5c33b1/2023-03-30-09-00-c8bc821f40d12ae27704adfb23f74547.pdf
Note: Project categories are based on ECR 1997.

In a study conducted between April 2019 and December 2021, Transparency International Bangladesh surveyed 353 industries in the Dhaka and Chattogram metropolitan areas, finding that 51 percent of those industries operated with an expired ECC and about 30 percent of them had applied for an ECC renewal. Based on the previous ECR, 22 percent of Red category projects reportedly received an ECC even without submitting an EIA (Transparency International Bangladesh 2022) (figure 4.1).

Figure 4.1. Renewal of ECCs in select industries



Source: Transparency International Bangladesh 2022.

These shortcomings raise questions about the effectiveness of the ECC system. Approving and renewing so many ECCs are clearly beyond DoE's capacity. As a point of comparison, an average of 269 EIAs were filed in the United States annually between 2017 and 2021.[37] Based on the previous ECR, the DoE was required to review an IEE for Orange B projects and EIA for Red projects. Given that most projects approved during 2015–2022 fell in the Orange B category and the high number of Red projects during this period, the ECC system created a growing workload for the DoE that was not matched with corresponding increases in budget and staff. In addition, most of the Red projects are related to power, water resources, land resources, and infrastructure-development projects. Reviewing these reports requires very specific expertise, but only DoE staff participated in this process under the ECR 1997. Therefore, there is a high risk that lack of relevant expertise in the EC Committee and public consultations resulted in poor-quality EIA reports.

Despite strengthening the ECC process, the ECR 2023 will generate additional workload for the DoE, such as public consultations for EIAs and on-site inspections for all project categories, and pressure on its officers to comply with deadlines. Without adequate resources, the DoE will not be able to fully implement the new ECR, with a risk of generating a backlog of applications and approving substandard clearances.

4.9 Conclusions and recommendations

Although EIAs by themselves do not lead to significant environmental improvements, they can work as powerful informational tools and lead to increased public participation and environmental awareness (Hironaka and Schofer 2002; Meyer et al. 1997; Rea and Frickel 2000). In Bangladesh, as in many other countries, the EC process tends to focus on meeting pro forma legal requirements, rather than concrete actions to improve the project's environmental performance beyond minimum requirements for managing negative environmental effects. Thus far, these assessments have (a) lacked effective public participation to inform project development, and (b) have resulted in recommendations that are seldom monitored and enforced.

By making the EC its predominant environmental management tool (chapter 3), Bangladesh has not taken sufficient advantage of EC's potential role in opening decision-making to public scrutiny. A major challenge in increasing the effectiveness of EIA to improve decision-making is to develop an economically efficient environmental policy and regulatory framework in which different command-and-control regulations, market-based instruments, and information and disclosure tools complement one another (chapter 9).

As a first measure, the DoE should conduct an in-depth, independent evaluation of the conditions that have been included in ECCs for Red and Orange category projects and assess their effectiveness and efficiency in mitigating the project's impacts, including a mitigation-hierarchy approach. This analysis would allow the DoE to extract common challenges and lessons to inform policy formulation—not only for improving the EC process, but also for further regulations dealing with specific technical requirements.

As mentioned in the National Environmental Policy 2018 and the 8th FYP, the GoB should amend the ECA or adopt a specific act to require SEAs for policies, programs, and plans, and establish the mandates and procedures for those assessments. For example, the GoB should evaluate whether the DoE or the Planning Commission would oversee SEAs.

Although the ECR 2023 is expected to improve the EC process, additional amendments and guidelines are required to clarify and strengthen assessment criteria and procedures related to key themes. In this revision, the GoB should consider exempting projects that are not expected to cause significant environmental impacts (Green and some Yellow projects) from the ECC process and instead focus on regulating them through other instruments, such as technical standards for specific activities or land-use zoning. This exemption should be accompanied by other reforms and investments to ensure that enforcement can be effectively done through other policy instruments (chapter 9).

In addition, the MoEFCC and the DoE should consider in those new regulations and guidelines (a) clarifying the screening of projects that are not pre-categorized in the ECR, beyond the pollution criteria envisaged in Schedule 14 of the ECR 2023; (b) requiring an analysis of project alternatives (including the "no-go" option); (c) strengthening the monitoring program after ECC issuance; (d) additional themes such as resource efficiency, impact to and from climate change, OHS, CHS, labor and workers' rights in collaboration with relevant government agencies and referring to applicable legislation in other sectors; (e) differentiated treatment of vulnerable groups in the assessment and management measures; (f) specific regulations for framework projects or programs, which should follow an environmental and social management framework; and (g) expanding the requirements of stakeholder consultations and access to information to other project categories.

In the short-term, the DoE also needs to (a) revise the EIA Guidelines for Industres 2021, updating and expanding their contents as per the ECR 2023; and (b) develop guidelines for non-industry projects, preferably by sector, which could be based on guidance instruments issued by international organizations. These guidelines should be gazetted and made legally binding. These reforms must be accompanied by adequate resources at the DoE, including increased and more stable headcount, increased budget, and equipment.

To strengthen enforcement as a follow-up of the ECC process, the DoE should consider (a) making its ECC processing and tracking software easily accessible to the public and expand its coverage to ECC monitoring activities; (b) enhancing other enforcement activities instead of conducting on-site inspections for ECC renewals of Green and Yellow projects, which have limited efficacy; (c) using a third-party system to conduct the monitoring of environmental and social indicators for high-risk projects; and (d) other mechanisms that can help reduce incentives for rent-seeking behavior.

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Endnotes

[35] Schedule 9 of the ECR 2023 includes the guidelines applicable to project location and provides additional details, such as the buffer distances that should be considered between different types of projects and sensitive areas. Projects that will be developed in export-processing zones, economic zones, and in the Bangladesh Small and Cottage Industries Corporation's industrial cities are exempted from the site-clearance requirement.

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CHAPTER 5. COST-BENEFIT ANALYSIS OF ENVIRONMENTAL HEALTH-RISK INTERVENTIONS

5.1 Introduction

In Bangladesh, the annual cost of environmental pollution associated with the five major environmental health-risk factors is estimated at the equivalent of 17.6 percent of GDP in 2019, as elaborated in chapter 2. Numerous interventions are available to mitigate, control, and prevent many of these health effects at a wide range of costs with varying levels of effectiveness.

This chapter aims to identify interventions that promise the greatest environmental health improvements or benefits per taka spent on the interventions. It analyzes the benefits and costs of potential interventions to mitigate health effects for all five major risk factors (table 5.1). The analysis presents benefit-cost ratios (BCRs) of interventions—with BCR being the ratio of benefits to costs. A BCR greater than one indicates that the benefits are greater than costs, with benefits and costs discounted at an annual rate of 5 percent.

Table 5.1 Scope of the cost-benefit analysis of environmental health interventions in Bangladesh

Environmental health-risk factor	Interventions (I's)	# I's
$PM_{2.5}$ ambient air pollution	Interventions in various sectors	21
$PM_{2.5}$ household air pollution from the use of solid fuels for cooking	Cleaner cooking (improved biomass cookstoves, liquified petroleum gas (LPG), electric stoves)	4
Lead exposure	Iron supplementation for young children, mitigation of lead exposure from recycled aluminum cookware, and rehabilitation of abandoned used lead acid battery (ULAB) recycling site	3
Microbiological pollution from Inadequate drinking-water quality Inadequate household sanitation Inadequate hygiene	 Household point-of-use treatment (POUT) of drinking water Pour-flush/flush toilets with septic tank Adequate handwashing with soap	 6 2 4
Arsenic in drinking water	Deep tube wells, pond sand filtering, and household filtering of drinking water	3

Source: World Bank.

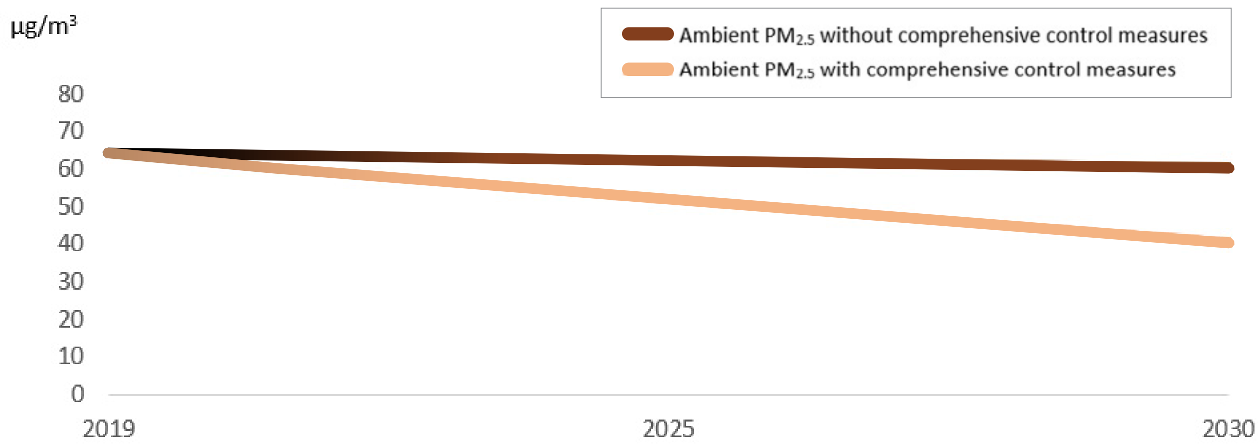
5.2 Benefits and costs of $PM_{2.5}$ ambient air pollution control interventions

Annual deaths from population exposure to ambient $PM_{2.5}$ and household $PM_{2.5}$ air pollution from the use of solid fuels is estimated at nearly 160,000 in 2019, along with 2.6 billion days lived with illness. Therefore, improvements in ambient $PM_{2.5}$ air quality and the use of clean fuels and technologies for cooking can provide substantial health benefits such as reduced cardiovascular, respiratory and type 2 diabetes illness and mortality.

The World Bank employed the GAINS[38] model of the International Institute for Applied Systems Analysis (IIASA) to identify cost-effective or least-cost $PM_{2.5}$ control measures for reaching potential ambient $PM_{2.5}$ targets for 2030 (World Bank 2022). The model was also employed to study air quality improvements and associated pollution abatement costs including marginal costs of $PM_{2.5}$ control measures and their effect on ambient $PM_{2.5}$ in Bangladesh in 2030 (Wagner et al. 2020).[39]

Applying the results from the two studies, estimated ambient $PM_{2.5}$ in Bangladesh is reduced from 61 μg/m^3 to 41 μg/m^3 in 2030 by implementing least-cost control measures (figure 5.1). These measures include eliminating household use of solid fuels by 2030 by switching to LPG or electricity for cooking.

Figure 5.1 Ambient $PM_{2.5}$ in Bangladesh, 2019–30 | *μg/m³*



Source: World Bank.

5.2.1 Costs of interventions to control $PM_{2.5}$ ambient air pollution

The GAINS cost-effectiveness analysis for Bangladesh presents 165 measures to control $PM_{2.5}$ and its precursors that are grouped into 21 categories. Control measures from 13 categories for which benefits are larger than the costs of the measures are presented in table 5.2 and figure 5.2.[40] Costs are expressed in constant prices to 2030.[41] Cost ranges from less than zero to $161 million (Tk 13,524 million) per year per μg/m³ improvement in ambient $PM_{2.5}$. These interventions are estimated to reduce ambient $PM_{2.5}$ from 61 to 41 μg/m³ in 2030, providing a 20 μg/m³ improvement in ambient $PM_{2.5}$.

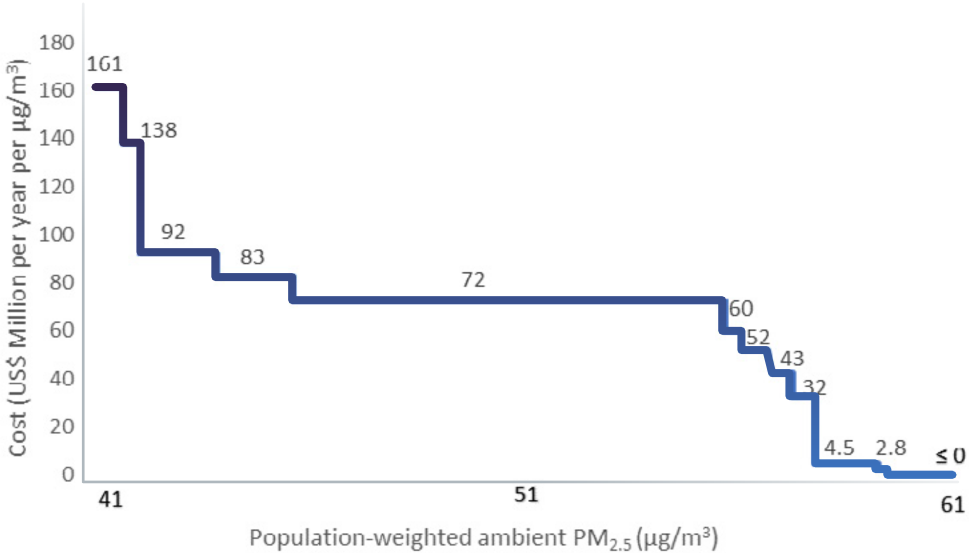
Control measures include reducing household use of solid fuels. Solid-fuel use affects both indoor $PM_{2.5}$ air pollution and outdoor ambient $PM_{2.5}$ concentrations since smoke from solid-fuel combustion escapes through chimneys, doors, windows, and other openings. Households switching to LPG for cooking provide the greatest reduction in ambient $PM_{2.5}$ followed by nitrogen oxides (NO_x) and sulfur dioxide (SO_2) ($PM_{2.5}$ precursors) control in power plants, eliminating solid waste burning by recycling and organic waste management. Other measures for which the benefits exceed the costs include Stage 2 standards for buses, SO_2 control in industry, Stage 24 standards for trucks, and Stage 4 standards for cars. The cumulative reduction in ambient $PM_{2.5}$ from these measures is minimal (0.06 μg/m³) and not reflected in table 5.2 and figure 5.2.

Table 5.2 Cost of $PM_{2.5}$ control measures | *Million $ per year per μg/m³ of ambient $PM_{2.5}$ improvement*

Control measures	Cost
Agricultural fertilizer – improved management	161
Agricultural livestock – manure management	138
Power plants – NO_x control	92
Power plants – SO_2 control (FGD)	83
Cooking with LPG	72
Power plants – PM control	60
Off-road – stage 3 to 6 standards	52
Industry – NO_x control	43
Engines – NO_x control	32
Agricultural residue – ban burning	5
Industry – PM control	3
Solid waste recycling and rural organic waste management	≤ 0
Cleaner small combustion devices	≤ 0

Source: World Bank, based on data in Wagner et al. (2020) and World Bank (2022).
Note: Cost less than or equal to zero (≤0) means that the intervention yields monetary benefits that off-set or more than off-set the cost.

Figure 5.2 Cost of $PM_{2.5}$ control measures | Million \$ per year per μg/m³ of ambient $PM_{2.5}$ improvement



Source: World Bank, based on data in Wagner et al. (2020) and World Bank (2022).
Note: Cost less than or equal to zero (≤0) means that the intervention yields monetary benefits that offset or more than offset the cost.

5.2.2 Benefits of interventions for controlling $PM_{2.5}$ ambient air pollution

The benefits estimated here of the $PM_{2.5}$ control measures are limited to health improvements and, as a result, are conservative. The health benefits of comprehensive $PM_{2.5}$ control measures are estimated for three scenarios in 2030: (a) $PM_{2.5}$ control measures without changes in household use of solid fuels; (b) control measures eliminating household use of solid fuels without other $PM_{2.5}$ control measures; and (c) $PM_{2.5}$ control measures including elimination of household use of solid fuels.

The first and second scenarios are estimated to reduce population-weighted ambient $PM_{2.5}$ by about an equal magnitude of 10 μg/m³. The third scenario results in an improvement equal to the sum of the first two scenarios. However, the estimated health benefits in each scenario are very different (table 5.3):

- Annual deaths avoided (42,000) in the second scenario are four times as high as in the first scenario (10,800);
- Annual deaths avoided in the third scenario are nearly 61,300. This is 36 percent of the baseline deaths from $PM_{2.5}$ that would prevail in 2030 in the absence of $PM_{2.5}$ control measures; and
- Annual deaths avoided in the third scenario are nearly 8,500 more than the sum of the first two scenarios.

In the first scenario, the benefit is limited to improvement in ambient $PM_{2.5}$. The second scenario brings two benefits: ambient $PM_{2.5}$ improvement and elimination of $PM_{2.5}$ household air pollution from the use of solid fuels. The third scenario achieves substantial health benefits beyond the sum of benefits in the first two scenarios. This is because incremental health benefits increase at lower ambient $PM_{2.5}$ concentrations.[42] Thus incremental health benefits are increasing the more $PM_{2.5}$ exposure is reduced. This is the case in the third scenario at ambient $PM_{2.5}$ of 41 μg/m³ versus 51 μg/m³ in the first and second scenario.[43]

Table 5.3 Annual deaths avoided in Bangladesh from comprehensive $PM_{2.5}$ control measures, 2030

		Reduction in population weighted ambient $PM_{2.5}$ (μg/m³)	Annual deaths avoided	Annual deaths avoided (% of baseline deaths)
1	Comprehensive $PM_{2.5}$ control measures (with no reduction in household use of solid fuels)	10	10,783	6
2	Elimination of household use of solid fuels (without other $PM_{2.5}$ control measures)	10	42,021	24
3	Comprehensive $PM_{2.5}$ control measures including elimination of household use of solid fuels	20	61,290	36

Source: World Bank estimates.

The estimated health benefits from the three scenarios can be expressed in terms of annual deaths avoided per μg/m³ of improvement in population-weighted ambient $PM_{2.5}$ (table 5.4), which shows the following:

- Eliminating household use of solid fuels results in 4,202 avoided deaths per year for each μg/m³ improvement in ambient $PM_{2.5}$. This is four times as effective as other $PM_{2.5}$ control measures that provide the same ambient $PM_{2.5}$ improvement but no change in household use of solid fuels; and
- $PM_{2.5}$ control measures are 80 percent more effective in avoiding deaths if household use of solid fuels is eliminated.

Table 5.4 Annual deaths avoided per μg/m³ improvement in ambient $PM_{2.5}$ in Bangladesh, 2030

	Annual deaths avoided per μg/m³ improvement
Elimination of household use of solid fuels (for example, switching to LPG or electricity), and no other $PM_{2.5}$ control measures	4,202
Comprehensive $PM_{2.5}$ control measures for ambient $PM_{2.5}$ improvements (with elimination of household use of solid fuels)	1,927
Comprehensive $PM_{2.5}$ control measures for ambient $PM_{2.5}$ improvements (with no reduction in household use of solid fuels)	1,078

Source: World Bank estimates.

Avoided deaths and illness are valued by applying the methodologies in appendixes H and I. The annual benefits of switching from biomass to LPG or electricity for cooking are Tk 68,665 million per μg/m³ improvement in ambient $PM_{2.5}$, and Tk 31,488 for other least-cost comprehensive $PM_{2.5}$ control measures (table 5.5).

Table 5.5 Benefits of $PM_{2.5}$ control interventions per year per μg/m³ improvement in ambient $PM_{2.5}$

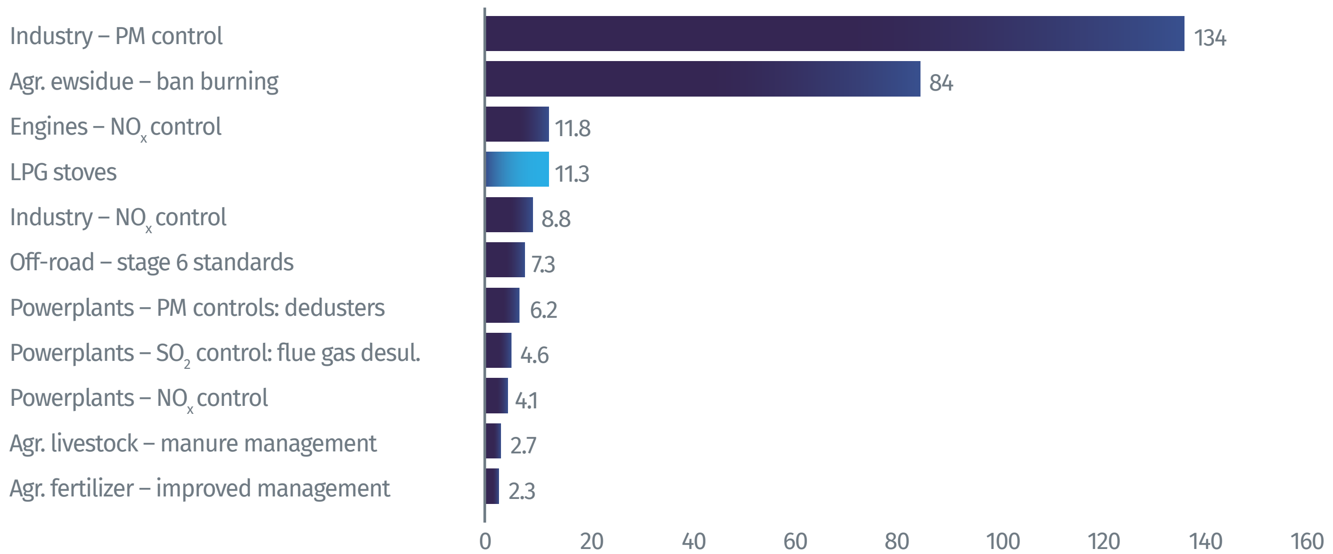
	Tk, millions	$, millions
Benefits of LPG and electricity for cooking	68,665	817
Benefits of other comprehensive $PM_{2.5}$ control measures	31,488	375

Source: World Bank estimates.
Note: Benefits are in 2019 constant Tk.

5.2.3 Benefit-cost ratios of interventions to control $PM_{2.5}$ ambient air pollution

BCRs of the $PM_{2.5}$ control measures range from 2.3 to 134, indicating that health benefits are Tk 2 to Tk 134 for each Tk spent on these measures (figure 5.3). Only three measures have a BCR larger than for LPG for cooking because LPG per μg/m³ also brings the benefits of household air pollution control (see table 5.10).[44]

Figure 5.3 Benefit-cost ratios of $PM_{2.5}$ control measures



Source: World Bank estimates.

The cost of the comprehensive $PM_{2.5}$ control measures for which benefits exceed costs is $1.3 billion (Tk 109 billion) per year while the benefit of these measures is $11.4 billion (Tk 954 billion). This gives a BCR of 8.8. Switching to cooking with LPG represents 57 percent of the cost and 73 percent of the benefit (table 5.6).

Table 5.6 Cost and benefits of comprehensive ambient $PM_{2.5}$ control measures | *$, millions, per year*

	Costs	Benefits	BCR
Lowest cost measures for first 5 μg/m³ improvement in ambient $PM_{2.5}$ (not LPG)	79	1,250	15.9
Lowest cost measures for next 5 μg/m³ improvement in ambient $PM_{2.5}$ (not LPG)	481	1,861	3.9
LPG for cooking for next 10 μg/m³ improvement in ambient $PM_{2.5}$	732	8,252	11.3
For cumulative 20 μg/m³ improvement in ambient $PM_{2.5}$	1,292	11,362	8.8

Source: World Bank estimates.
Note: Costs and benefits are in constant 2019 values.

Further ambient $PM_{2.5}$ air quality improvements can be achieved but only at increasingly higher costs. Such control measures were assessed by GAINS. Cumulative reductions in ambient $PM_{2.5}$ from these measures are 3.5 μg/m³, or less than 15 percent of reductions from lower cost $PM_{2.5}$ control measures that have BCR greater than one. The total cost of high-cost measures is nearly $4 billion per year per μg/m³ while total benefit is $1.25 billion, with a BCR of 0.3. The measures include further control of vehicle emissions, primary $PM_{2.5}$ and $PM_{2.5}$ precursors from industry and power plants, emissions from engines and small combustion devices, urban organic waste management (instead of burning), and measures in the agricultural sector. The remaining ambient $PM_{2.5}$ concentrations estimated to prevail after implementation of the comprehensive measures discussed above are largely due to transnational $PM_{2.5}$ pollution from neighboring countries, and secondly due to natural sources and $PM_{2.5}$ and precursor emissions for which abatement cost is likely to exceed benefits.

5.2.4 Conclusions regarding interventions to control $PM_{2.5}$ ambient air pollution

The health effects of population exposure to ambient $PM_{2.5}$ and $PM_{2.5}$ household air pollution will continue to be enormous unless comprehensive $PM_{2.5}$ control measures are undertaken. Comprehensive $PM_{2.5}$ control measures may reduce ambient $PM_{2.5}$ by as much as 33 percent by 2030 which include interventions to eliminate burning of solid waste and improved management of agricultural fertilizers and livestock manure in addition to traditional sectors of pollution such as power plants, industry, and road vehicles. It will also require a full substitution from household use of solid fuels to LPG or electricity as household use of solid fuels is the largest single contributor to elevated ambient $PM_{2.5}$. BCRs of comprehensive $PM_{2.5}$ control measures that provide one-third improvement in ambient $PM_{2.5}$ range from 2 to 134, rather 127 indicating health benefits are Tk 2 to 134 for each Tk spent on these measures. Additional $PM_{2.5}$ control measures were also assessed which may further improve ambient $PM_{2.5}$ by 5 percent, but at a cost that is substantially higher than the value of expected health benefits. Further ambient $PM_{2.5}$ improvements can be achieved by collaborating with neighboring countries (especially with India) to address transnational $PM_{2.5}$ pollution and benefit all countries involved.

5.3 Benefits and costs of interventions to control household air pollution

About 74 percent of Bangladesh's population used solid fuels as the primary cooking fuel in 2022 according to the Population and Housing Census 2022 (BBS 2022). Cooking with clean energies (for example, electricity, LPG, natural gas, biogas) was practiced by 26 percent of the population. About 8.8 million improved biomass cookstoves (ICSs) have been distributed. These are 5 million Bondhu Chula chimney stoves and 3.8 million IDCOL stoves most of which are a single burner portable stove without chimney (see chapter 2). This means that up to 21 percent of households in Bangladesh have an ICS if all stoves are still in use, and at least 53 percent still use traditional cookstoves (TCS). Among those using solid fuels, 25 percent cook in the main house, 42 percent in a separate building, and 33 percent cook outdoors (BBS/UNICEF 2019).

This report assesses the benefits and costs of cookstove interventions for households that still use TCS. The interventions reduce household $PM_{2.5}$ air pollution from the use of solid fuels. The interventions are programs for household adoption of ICSs, LPG, and electric cooking devices. Some ICSs are portable single-burners with no venting of smoke, others are single-, double-, or even triple-burner stoves with chimney. LPG stoves have one to four burners. Electric cooking devices include conventional electric stove (ES), electric induction stove (EIS), electric rice cooker and electric pressure cooker (Saha, Razzak, and Khan 2021; World Bank 2021). As rice cookers and pressure cookers are becoming increasingly popular, they are used in combination with ICS, LPG, or other electric cooking devices.

The intervention stoves and devices assessed are (a) single-burner ICS without chimney; (b) ICS with chimney and two burners; (c) LPG stove with two burners; (c) conventional ES with two plates plus rice cooker or pressure cooker; and (d) EIS with two plates plus rice cooker or pressure cooker.

Household use of solid fuels has community effects and wider regional effects. An ICS with chimney is more effective for the household than a single-burner chimneyless stove but contributes more to increased outdoor ambient pollution and household pollution in nearby dwellings. Only clean energies and technologies prevent these externalities. To achieve the maximum benefits per unit of expenditure on household energy and stove interventions, all households in a community need to participate, and thus achieve a "clean cooking" or an "improved cookstove" community. This concept is especially applicable to clustered household communities.

Two burner stoves make households less likely to continue using their TCS(s) to meet their cooking needsThe intervention distinction between conventional electric stove and electric induction stove is made due to the significantly higher energy efficiency of the induction stove. Benefits of the interventions are assessed in three household cooking environments with different air pollution exposure levels: (a) cooking in the house; (b) cooking in a separate building; and (c) cooking outdoors to reflect the main cooking practices in Bangladesh.

Pre- and post-intervention assessment is undertaken with respect to (a) household members' reduction in $PM_{2.5}$ exposure resulting from the intervention; (b) health benefits of household members' reduced $PM_{2.5}$ exposure; (c) household non-health benefits (that is, fuel and cooking-time savings); and (d) stove and energy costs of interventions.

5.3.1 Pre-intervention $PM_{2.5}$ exposures in households

Pre-intervention $PM_{2.5}$ exposures refer to exposures in households that still use TCSs. One study measured personal $PM_{2.5}$ exposures averaging 144 μg/m^3 among 200 adult women cooking with solid fuels in TCS in rural areas in Chittagong and Dhaka divisions. Measurements were conducted over a 48-hours period once in the dry season and once in the wet season (Shahriar et al. 2021). More recently, a study of 300 adult women in five divisions measured personal $PM_{2.5}$ over a 24-hour period in the dry season (Berkeley Air Monitoring Group 2022). Personal exposures averaged 236 μg/m^3 among the women cooking with TCS. The personal exposures in these two studies include the exposure to ambient $PM_{2.5}$ in addition to $PM_{2.5}$ from household use of solid fuels. Subtracting ambient $PM_{2.5}$ gives net household air pollution personal exposure among adult women of 87 μg/m^3 based the study by Shahriar et al. and 124 μg/m³ based on the study by Berkeley Air Monitoring Group.[45] The average exposure from the two studies is 106 μg/m³ and is used here as the pre-intervention $PM_{2.5}$ exposure for adult women. Personal exposures for adult men and children are estimated using men/women and children/women exposure ratios of 64 and 85 percent, respectively, from the Global Burden of Disease (GBD) 2019 that is based on a review of personal exposure studies globally. These ratios reflect that men and young children generally spend less time in the household environment and the kitchen than adult women. Average pre-intervention exposure from the use of solid fuels for all household members is therefore 87 μg/m³. This is an average across all household cooking locations (table 5.7). Personal exposures from cooking outdoors or in a separate building are set at 60 and 80 percent, respectively, of exposure from cooking in the house.

Table 5.7 Long-term personal $PM_{2.5}$ exposure from solid fuels by cooking location in households using traditional cookstoves | *μg/m³*

	Adult women	Adult men	Children < 5 years	Average
Average across all cooking locations	106	68	90	87
Cooking in house	135	86	115	111
Cooking in separate building	108	69	92	89
Cooking outdoors	81	52	69	66

Source: World Bank estimates.
Note: The estimates are net of exposure to ambient $PM_{2.5}$.

5.3.2 Post-intervention $PM_{2.5}$ exposures in households

The use of ICSs, LPG, and electric stoves is expected to reduce household members' exposure to $PM_{2.5}$ from cooking. Review of personal exposure studies before and after installation of an ICS indicates a reduction in exposure of 50–60 percent (Larsen 2017; Pope et al. 2017; Shupler et al. 2018). In Bangladesh, the study by Berkeley Air Monitoring Group (2022) found that $PM_{2.5}$ gross and net personal exposures among households using the ICSs by IDCOL were, respectively, 23–39 and 44–75 percent lower than exposures in households using TCSs. Net personal exposure is the exposure from the use of solid fuels—that is, gross personal exposure less ambient $PM_{2.5}$. Personal exposures were lowest in the households using double-burner chimney stoves as this stove allows most households to not having to also use the TCS for their cooking needs. Among the households that used ICSs personal exposures were highest among those using the single-burner portable stove without chimney (table 5.8).

Table 5.8 Personal $PM_{2.5}$ exposure reduction from ICS

	TCS	ICS single-burner portable stove	ICS single-burner chimney stove	ICS double-burner chimney stove
$PM_{2.5}$ gross personal exposure (μg/m³)	236	181	167	143
Reduction in gross personal exposure (%)		-23	-29	-39
Ambient $PM_{2.5}$ exposure (μg/m³)	112	112	112	112
$PM_{2.5}$ net personal exposure (μg/m³)	124	69	55	31
Reduction in net personal exposure (%)		-44	-56	-75

Source: Based on Berkeley Air Monitoring Group (2022) and ambient $PM_{2.5}$ data from DoE (2023).
Note: TCS = Traditional cookstove; ICS = Improved biomass cookstove.

Exposure reductions over the life of the ICS are likely to be less than observed at any point during its useful life since the quality of the ICS deteriorates over time. Consequently, 40 and 65 percent reductions in net personal exposure are applied here for the ICS single-burner stove without chimney and the ICS double-burner stove with chimney, respectively. This reduction is applied to households cooking in the house. Exposure reductions from an ICS for households cooking in a separate building or outdoors may be less than for households cooking in the house, because an ICS would provide less exposure reduction to household members who tend to spend less time in these locations than in the house. Thus, lesser exposure reductions are applied to households cooking in a separate building and outdoors (table 5.9).

Table 5.9 Personal $PM_{2.5}$ exposure reduction from ICS by cooking location | *Percent reduction*

	Exposure reduction from single-burner ICS without chimney	Exposure reduction from double-burner ICS with chimney
In house	40	65
Separate building	35	55
Outdoors	25	40

Source: World Bank estimates.
Note: ICS = Improved biomass cookstove.

LPG combustion results in very little $PM_{2.5}$ emissions and is considered a relatively clean cooking fuel. The total personal exposure to $PM_{2.5}$ among households exclusively using LPG is thus determined by ambient air pollution including $PM_{2.5}$ from neighboring households using solid fuels. It is therefore stipulated that personal exposure levels in households exclusively using LPG are zero from cooking and total exposure is ambient $PM_{2.5}$ concentration level. These exposure levels are also applied to households using electric stoves.

5.3.3 Costs of interventions to control household air pollution

Many ICS programs have suffered from low adoption and user rates, poor maintenance, and outright abandonment of the ICS in favor of the old TCS (Hanna, Duflo, and Greenstone 2016; Miller and Mobarak 2015; Mobarak et al. 2012). This is particularly the case with programs that are not demand driven—that is, when stoves are distributed for free or at a highly subsidized rate whether or not households want the stoves (Hanna, Duflo, and Greenstone 2016). Thus, for large-scale adoption of cleaner cookstoves and cooking energies to occur several factors influencing adoption rates must be addressed, such as: (a) high initial cost of ICSs; (b) high annual fuel cost of LPG fuel and electricity; (c) tailoring to consumers' preferences for stove characteristics; (d) installment financing of stoves and LPG auxiliary equipment (gas cylinder, hose, connection); (e) well-targeted information campaigns; and (f) community focus similar to total sanitation and "open defecation free" community programs.

Kar and Zerriffi (2015) present a theoretical framework for achieving successful stove-promotion programs. The framework stipulates that behavior change for stove adoption and proper use is a process that unfolds over time through a series of six distinct stages. The stages are (1) precontemplation, (2) contemplation, (3) preparation, (4) action, (5) maintenance, and (6) termination. For stove-promotion programs to be successful, they must consider each stage. This includes well-designed behavioral change communication (BCC) strategies, overcoming obstacles to stove adoption (for example, identify desirable stove technology and design, stove financing, warranty, stove satisfaction guarantees), stove servicing and maintenance follow-up.

5.3.4.1 Cost of stoves and equipment

The costs of interventions are (a) stove and equipment cost; (b) stove maintenance and repair cost; (c) cost of program to promote the intervention; and (d) energy cost. The cost of ICSs varies depending on fuel and emission efficiency, number of burners, durability, materials, and technology. The cost of three main types of the ICS from IDCOL range from Tk 375 for a portable single-burner stove without chimney to Tk 1,350–1,450 for single- and double-burner stoves with chimney (World Bank 2021). Most sales are portable single-burner stoves without any chimney. A popular alternative ICS is the Bondhu Chula stove with one to three burners and chimney for Tk 800–1,200 (Ahmed and Iqbal 2018).

The cost of an LPG stove with two burners ranges from Tk 2,500 to Tk 7,000. The additional costs of a gas cylinder, hose, and gas regulator total about Tk 2,000. The cost of a conventional ES with two plates is similar to the cost of LPG stove. The cost of EIS is often higher.

Table 5.10 presents stove and device costs and their useful life. Costs are annualized at a 5 percent discount rate and the useful life of the stoves and devices ranges from 5 to 10 years. Annual maintenance and repair cost is 5 percent of the initial cost.

Table 5.10 Cost of stoves and devices per household

	ICS single burner without chimney	ICS double burner with chimney	LPG	ES	EIS
Cost of stove (Tk)	375	1,200	4,000	4,000	5,000
Cost of cylinder, hose, regulator) (Tk)	n.a.	n.a.	2,000	n.a.	n.a.
Rice cooker or pressure cooker (Tk)	n.a.	n.a.	n.a.	3,000	3,000
Useful life of stoves and devices (years)	5	5	10	10	10
Annualized cost per household (Tk)	82	264	740	863	987
Annual stove maintenance and repair (5% of stove and device cost)	19	60	300	350	400
Total annualized cost per household (Tk)	**101**	**324**	**1,040**	**1,213**	**1,387**

Source: World Bank estimates.
Note: Discount rate is 5 percent. n.a. = Not applicable; ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

5.3.4.2 Cost of promotion program

The promotion cost applied for achieving high adoption rates of ICSs and clean technologies is Tk 1,000 per targeted household. The program also monitors and follows up to maximize long-term user rates and proper stove maintenance and repair. Annualized cost is Tk 123–220 per household (table 5.11).

Table 5.11 Cost of promotion program per household

	ICS	LPG	ES	EIS
Cost of program per household (Tk)	1,000	1,000	1,000	1,000
Annualized over life of stove (years)	5	10	10	10
Annualized program cost per household (Tk)	220	123	123	123

Source: World Bank estimates.
Note: Discount rate is 5 percent; ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

5.3.4.3 Cost of energy

Biomass fuel: As many as 80 percent of the population in Bangladesh that use biomass for cooking live in rural areas. Most of these households collect fuelwood or agricultural residues. Many households in small urban areas also collect fuelwood. A value of self-collected biomass fuels is commonly imputed based on time spent to collect biomass fuel. A collection time of 30 minutes per household per day is applied for households cooking with biomass using TCSs.[46] The value of this collection time is estimated with average rural female wages and a value of time equal to 50 percent of the wage rate. Rural female wage rate is applied as most fuel collection is carried out by women and takes place in rural areas. The estimated value of biomass collection is Tk 7,025 per household per year.[47] This is the pre-intervention energy cost for households using TCS. With ICS, energy savings are 30–50 percent (Ahmed and Iqbal 2018; World Bank 2021). Savings of 40 percent are applied for both the ICS single-burner portable stove and the ICS double-burner chimney stove because of their fairly similar thermal efficiency (Berkeley Air Monitoring Group 2022). The energy cost using the two ICSs is thus Tk 4,215 per household per year (table 5.13).

LPG and electricity: The average annual LPG consumption is 186 kg per household for households using only LPG for cooking (World Bank 2021).[48] Based on the energy content of LPG and electricity, and stove efficiencies, cooking exclusively with an ES or EIS would require 2,054 kWh or 1,643 kWh per household per year, respectively, yielding an annual effective energy of 4,436 MJ. The lesser electricity consumption of the EIS arises from its higher energy efficiency (table 5.12).[49]

Table 5.12 Estimated household energy consumption for cooking

	LPG	ES	EIS
Energy content (MJ)	47.7 per kg	3.6 per kWh	3.6 per kWh
Stove efficiency	50%	60%	75%
Effective energy (MJ)	23.9 per kg	2.2 per kWh	2.7 per kWh
Consumption per household per year	186 kg	2,054 kWh	1,646 kWh
Total effective energy per household per year	**4,436 MJ**	**4,436 MJ**	**4,436 MJ**

Source: World Bank estimates.
Note: LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove; MJ = megajoule; kWh = kilowatt-hour.

The energy cost of using each of the interventions ranges from Tk 4,215 per household per year for the two ICSs to Tk 15,624 for LPG. The cost of using an EIS is Tk 10,417 (table 5.13). The economic price of LPG is assumed to be Tk 84 per kg. This is based on the long-term LPG export prices from producing countries, including transportation and distribution cost. The cost of using electric stoves is based on a residential electricity price of Tk 6.34 per kWh which recently was the tariff rate for consumers of 300–400 kWh of electricity per month. Cooking exclusively with electricity implies electricity consumption of 137–171 kWh per month, which would indicate a monthly household total consumption of 300–400 kWh. For households that use very little electricity, cooking exclusively with electricity could cost less.

Table 5.13 Cost of energy per household per year

	ICS	LPG	ES	EIS
Energy consumption	n.a.	186 kg	2,054 kWh	1,643 kWh
Cost per unit (Tk)	n.a.	84 per kg	6.34 per kWh	6.34 per kWh
Cost per household per year (Tk)	4,215	15,624	13,021	10,417

Source: World Bank estimates.
Note: Economic costs are exclusive of taxes and other levies; n.a. = Not applicable; ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

5.3.4.4 Total costs

The total cost of interventions amounts to Tk 4,536–16,787 per household per year (table 5.14). The cost is lowest for cooking with the two ICSs followed by EIS. The cost is highest for LPG. The largest cost for all interventions is energy-consumption cost, accounting for 87–93 percent of the total annual cost.

Table 5.14 Cost of interventions | *Tk per household per year*

	ICS single burner without chimney	ICS double burner with chimney	LPG	ES	EIS
Stove and devices	82	264	740	863	987
Stove and device maintenance and repair	19	60	300	350	400
Promotion program	220	220	123	123	123
Energy consumption	4,215	4,215	15,624	13,021	10,417
Total cost	**4,536**	**4,759**	**16,787**	**14,357**	**11,927**

Source: World Bank estimates.
Note: ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

5.3.5 Benefits of interventions to control household air pollution

Health benefits: An estimated 10,500 to 13,800 deaths could be avoided annually by 2030 if another 45 percent of the population switches from TCS to an ICS single-burner portable stove or to an ICS double-burner stove with chimney. If the same population switches from TCS to LPG or electricity for cooking instead, annual avoided deaths could be 41,700. These estimates incorporate the effect on population-weighted ambient $PM_{2.5}$ of reducing $PM_{2.5}$ emissions from household use of solid fuels.[50] Reduction in ambient $PM_{2.5}$ by 45 percent of the population switching from TCS to LPG or electricity for cooking is estimated at 10 μg/m^3 while the effect of switching to ICSs is about 5 μg/m^3.

Avoided deaths and illness are valued by applying the methodologies in appendixes H and I. This gives health benefits of interventions of Tk 9,166–36,344 per household per year (table 5.15). Benefits are higher for households cooking in the house than for households cooking in a separate building or outdoors, due to differences in pre-intervention and post-intervention exposure levels of $PM_{2.5}$. Health benefits of switching from TCS to clean cooking solutions (LPG, electricity) are 3–4 times higher than adopting one of the ICSs. Switching to ICS double-burner stove with chimney provides 25–40 percent higher health benefits that switching to ICS single-burner stove without chimney.

Table 5.15 Health benefits of interventions by cooking location | *Tk per household per year*

Cooking location	ICS single burner without chimney	ICS double burner with chimney	LPG	ES	EIS
In the house	11,152	15,613	39,247	39,247	39,247
In separate building	9,452	12,522	36,598	36,598	36,598
Outdoors	7,375	9,160	33,538	33,538	33,538
Average across all locations	**9,166**	**12,055**	**36,344**	**36,344**	**36,344**

Source: World Bank estimates.
Note: Average across all locations is weighted by the percentage of households cooking in each location. ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

Fuel and cooking-time savings: Switching from a TCS to an ICS, LPG, or electric stove also has non-health benefits. The main benefits are reduced biomass consumption and reduced cooking time. A collection time of 30 minutes per household per day is applied for households cooking with biomass fuel using TCS. The value of this collection time is estimated using average rural female wages and value of time equal to 50 percent of the female wage. Estimated value of biomass collection is Tk 7,025 per household per year.[51]

Households using TCSs spend on average 3.5 hours per day on cooking. The use of either of the two ICSs saves 10 minutes per day, and the use of clean cooking technologies such as LPG, gas, and electricity saves 40 minutes per day (World Bank 2019). As for biomass collection time savings, a value of time equal to 50 percent of female rural wage rates are applied to estimate value of cooking-time savings. Annual value of cooking-time savings per household per year are Tk 2,342 for the two ICSs and Tk 9,367 for cooking with LPG and electricity.

Total benefits: The total benefits of the cookstove interventions amount to Tk 18,533–52,736 per household per year (table 5.16). Benefits (Tk 52,736 per household per year) are the same for LPG, conventional ES, and EIS. Benefits of these three latter stoves are 2.5–2.8 times the benefits for the two ICSs due to the ICSs' lesser health benefits and smaller benefits in cooking-time savings benefits. The health benefits per household presented in table 5.16 are averages across cooking locations. Health benefits are somewhat larger for households cooking in the house and somewhat lower for households cooking in a separate building or outdoors as previously discussed.

Table 5.16 Benefits of interventions | *Tk per household per year*

	ICS Single burner without chimney	ICS Double burner with chimney	LPG	ES	EIS
Health benefits [a]	9,166	12,055	36,344	36,344	36,344
Fuel savings	7,025	7,025	7,025	7,025	7,025

	ICS Single burner without chimney	ICS Double burner with chimney	LPG	ES	EIS
Cooking-time savings	2,342	2,342	9,367	9,367	9,367
Total benefits	**18,533**	**21,422**	**52,736**	**52,736**	**52,736**

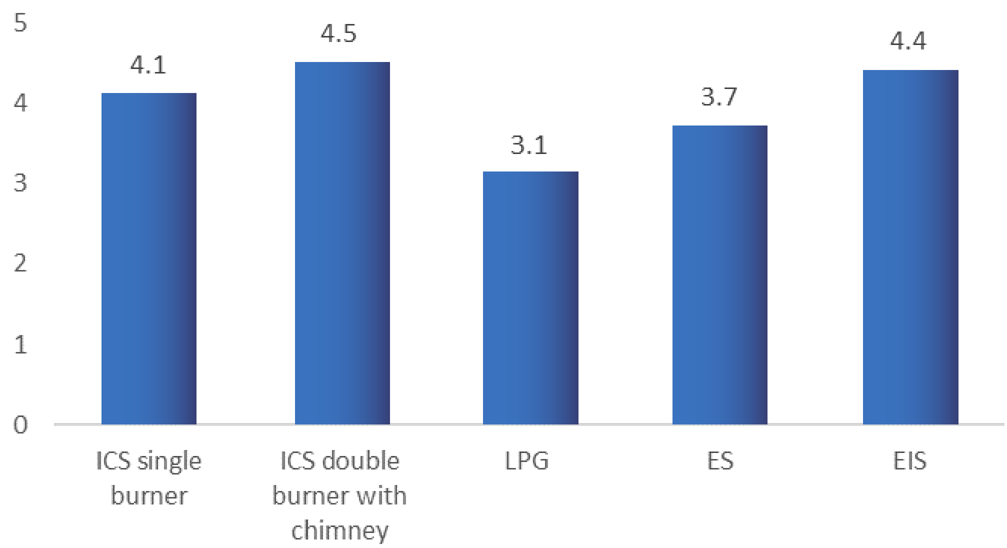
Source: World Bank estimates.
Note: [a] Average across all cooking locations; ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

5.3.6 Benefit-cost ratios of household air pollution control interventions

The BCRs of the interventions are in the range of 3.1 to 4.5, indicating that benefits are Tk 3.1–4.5 for every Tk spent on cleaner cooking (figure 5.4).[52] The BCR for the ICSs is higher than for LPG and conventional electric stove, but lower than or like the BCR for EIS. Moreover, total benefits of EIS are 2.5–2.8 times the benefits of the ICSs, as previously discussed.

While the BCRs for the two ICSs are comparable to the BCRs for LPG and electric stoves, LPG and electricity are the options to effectively combat the health effects of solid fuels. As such, ICSs may be reasonably efficient but not an effective solution for improving the health of the population. Health benefits will be especially large when clean cooking is achieved community-wide. However, the health benefits of cooking with electricity are influenced by the fuels and technologies used by power plants for electricity production. Therefore, the magnitude of health effects from incremental production of electricity by power plants for cooking with electricity needs to be assessed.

Figure 5.4 Benefit-cost ratios (BCRs) of interventions to control household air pollution



Source: World Bank estimates.
Note: ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

The BCRs vary with the household's cooking location. They are highest for households cooking in the house while only somewhat lower for households cooking outdoors (table 5.17).

Table 5.17 Benefit-cost ratios (BCRs) of interventions to control household air pollution by cooking location

Cooking location	ICS single burner without chimney	ICS double burner with chimney	LPG	ES	EIS
In the house	4.5	5.2	3.3	3.9	4.7
In separate building	4.1	4.6	3.2	3.7	4.4

Cooking location	ICS single burner without chimney	ICS double burner with chimney	LPG	ES	EIS
Outdoors	3.7	3.9	3.0	3.5	4.2
Average across all locations	4.1	4.5	3.1	3.7	4.4

Source: World Bank estimates.
Note: ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

The estimation of benefits and costs of the cookstove interventions assumes all households will adopt and sustain the use of the intervention stoves and properly maintain, repair, and replace them when appropriate. This assumption is unrealistic. Some households will continue using TCSs, some will purchase a new stove but return to also using their TCSs after some time, and some households will not adequately keep up their stoves for maximum benefits (Lewis et al. 2015; Pillarisetti et al. 2014; Ruiz-Mercado et al. 2013).

If only one-third of households switch to ICS, LPG, or electric stoves, and only two-thirds of those households sustain the use of the stoves through the stoves' useful life, then BCRs decline from 3.1–4.5 to 3.0–4.1 (table 5.18). This indicates that the BCRs are quite insensitive to household rates of cookstove adoption and sustained use. The influences of these factors on the BCRs are the cost of stoves, the cost of maintenance and repair, and the cost of promotion program per household that respond to the program.[53] These cost components are relatively small compared to the cost of energy, except for the ICSs. Therefore, the effect on the BCRs is somewhat larger for ICSs.

Table 5.18 Benefit-cost ratios (BCRs) of interventions to control household air pollution

Household response to promotion program	ICS single burner without chimney	ICS double burner with chimney	LPG	ES	EIS
Full response	4.1	4.5	3.1	3.7	4.4
Partial response [a]	3.5	3.8	3.0	3.5	4.1

Source: World Bank estimates.
Note: [a]33 percent of households adopt ICS, LPG, or electric stove, and 66 percent of these households sustain the use of the stoves through the stoves' useful life; ICS = Improved biomass cookstove; LPG = Liquified petroleum gas; ES = Electric stove; EIS = Electric induction stove.

5.3.6 Conclusions regarding interventions to control household air pollution

Noteworthy from the analysis of the interventions is that the BCRs for EIS are considerably higher than for LPG despite higher initial EIS stove cost. The higher BCRs are due to lower cost of cooking with EIS arising from the higher energy efficiency of EIS stoves than LPG stoves. However, the BCRs for EIS and ES depend on the electricity tariff rate paid by the household. For households paying above Tk 7.5 and Tk 9.2 per kWh, the BCRs for ES and EIS, respectively, are below the BCR for LPG. This is the case for households using more than 400 kWh per month. Promotion of electric cooking will also need to be assessed in relation to developments of supply and demand in the electricity sector.

While the BCRs for the ICSs may be higher than for LPG and conventional electric stoves, clean cooking technologies such as LPG and electricity are the options for effectively combatting the health effects of solid fuels. In other words, ICSs may be a reasonably efficient but not effective solution for improving the health of the population. Health benefits will be especially large when clean cooking is achieved community wide. Nevertheless, continued expansion of the ICS programs, and promotion of dual-burner stoves in particular, will continue to be important for households that cannot afford cooking with LPG or electricity. ICSs will also serve an important role in conserving scarce fuel wood and reduce the use of agricultural residue for cooking because of the higher energy efficiency of ICSs compared to TCSs.

One priority that emerges from the analysis is to further assess the potential for promoting the use of electric stoves—and perhaps especially induction stoves—for cooking. This is a cheaper option than LPG for small users of electricity that can benefit from lower residential block tariff rates for electricity. With residential block tariffs for electricity pricing, cooking with electricity provides an opportunity for less-well-off households to have this option as well. Further assessment is also warranted regarding the removal of any price and non-price obstacles and regarding the provision of incentives for adoption of LPG for cooking.

5.4 Benefits and costs of interventions to mitigate and prevent lead (Pb) exposure

This section assesses the benefits and costs of three interventions to mitigate Pb exposure: (a) a nutrition intervention found to have moderately positive effects on children's blood lead levels (BLLs); (b) switching from Pb contaminated cookware made of recycled aluminum to stainless steel; and (c) rehabilitation of abandoned used lead-acid battery (ULAB) recycling sites. Assessment of benefits and costs of other interventions are constrained by incomplete understanding of how much each source of lead exposure contributes to BLLs. Assessment of costs of various short- and long-term mitigation options are also much needed.

5.4.1 Nutrition intervention

One potential avenue to address elevated BLLs in children is nutrition interventions targeted at young children between six months and five years of age as well as for pregnant women. WHO (2021) reports that randomized controlled trials (RCTs) have found that iron and/or calcium supplementation provide a small reduction in children's BLLs but with low certainty of evidence. However, for zinc, one RCT found no evidence of effect on BLLs (table 5.19). Despite this low certainty, WHO recommends iron and/or calcium supplementation for children up to ten years of age that have a BLL equal to or greater than 5 μg/dL if the child has, or is likely to have, iron deficiency and/or inadequate calcium intake (WHO 2021).

Table 5.19 Effect of nutrition interventions on children's BLLs

Nutrient supplementation	Number of RCTs in children	Intervention effect on BLL	Strength of evidence
Iron	3 RCTs	Small reduction in iron-deficient children	Very low certainty
		No effect in children who are not iron deficient	Moderate certainty
Calcium	4 RCTs	Small reduction	Very low certainty
Zinc	1 RCT	No effect	Moderate certainty

Source: World Bank based on WHO (2021).
Note: RCT = Randomized controlled trial.

Well over half of young children in Bangladesh have BLLs greater than 5 μg/dL, since the mean BLL in children under five years of age is estimated at 6.4 μg/dL. Furthermore, around 40–45 percent of children under five years of age are anemic (Ahmed et al. 2021; Akpan et al. 2022; Pasricha et al. 2021) while iron deficiency (ID) stands at about 27 percent (Akpan et al. 2022; Pasricha et al. 2021). However, only six percent of children under five years of age are given iron supplements (NIPORT and ICF 2020). But iron fortification of food is on the rise (Ahmed et al. 2021). This section presents estimates of the benefits and costs of iron supplementation for children starting at the age of 6 months to the age of 59 months in terms of effects on BLLs as well as anemia.

5.4.1.2 Iron supplementation on children's BLLs

Three RCTs have assessed the effect of iron supplementation on BLLs in children (Kordas 2017). Two studies found a statistically significant effect on BLLs while one study found no effect (table 5.20). A study in Morocco found a 20 percent or 0.8 μg/dL reduction in mean BLLs as a result of iron-fortified biscuits with 8 mg of iron per day for 28 weeks. The reduction in mean BLLs increased to 35 percent from a combination of 8 mg of iron and 41 mg of EDTA (ethylenediaminetetraacetic acid).[54] The study in India did not report the effect of iron on mean BLLs but found that 15 mg of iron per day for 16 weeks reduced the number of children with BLLs above 10 μg/dL from 65 to 29 percent, a reduction of 55 percent. This is similar to the study in Morocco for children with BLLs greater than 5 μg/dL. The effect of iron on ID in the studies in India and Morocco was even more pronounced.

Table 5.20 Effects of iron supplementation on blood lead levels of children – three RCTs

	Mexico	India	Morocco	Morocco
Intervention	Iron tablets (30 mg iron per day) for 6 months	Iron-fortified rice meal (15 mg of iron per day) for 16 weeks	Iron-fortified biscuits (8 mg iron per day) for 28 weeks	Iron- and EDTA-fortified biscuits (8 mg iron and 41 mg EDTA per day) for 28 weeks
Participants	School children near a metal smelter complex	School children	School children	School children
Age (years)	6–7	5–9	7 (average)	7 (average)
Iron deficiency (ID)	Reduction not reported. 12% of children had ID at baseline	Children with ID reduced from 70% to 28% of children	Children with ID reduced from 35% to 5% of children	Children with ID reduced from 36% to 5% of children
Reduction in mean BLL	From 12.5 µg/dL to 10.9 µg/dL (not statistically significant)	–	From 4.1 µg/dL to 3.3 µg/dL (20% reduction)	From 4.41 µg/dL to 2.87 µg/dL (35% reduction)
Reduction in elevated BLLs	Reduction not reported. 57% of children had BLL ≥ 10 µg/dL at baseline	55% reduction in children with BLLs ≥ 10 µg/dL (from 65% to 29% prevalence)	52% reduction in children with BLLs > 5 µg/dL (from 27% to 13% prevalence)	66% reduction in children with BLLs > 5 µg/dL (from 32% to 11% prevalence)
Reference	Rosado et al. (2006)	Zimmermann et al. (2006)	Bouhouch et al. (2016)	Bouhouch et al. (2016)

Source: World Bank.
Note: – = Not available. RCT = Randomized controlled trial.

One possible reason for not observing a significant effect on BLL in the study in Mexico may be the low prevalence of ID of 12 percent compared to the prevalence of 70 and 35 percent in the India and Morocco studies, respectively, since the effectiveness of iron supplementation on BLL may be mainly for children with low iron. A second reason may be that the Pb exposure route may largely have been through inhalation of airborne Pb from the smelter complex in Mexico while iron supplementation may be most effective against Pb ingested through the gastrointestinal tract. A third reason may be the persistently high exposure to Pb from the metal smelter complex before and during iron-supplementation intervention.

5.4.1.3 Cost of nutrition intervention

The cost of iron supplementation has two components: The first component is the cost of iron supplements in the form of tablets, syrups, or fortification of food. Iron syrup with a dose of 12.5 mg of iron per day costs $0.63 per child for a three-month supply (Apkan et al. 2022). The second component is the cost of promoting and delivering the iron supplement to the targeted children. This cost is reported at $4.5–5.8 per child (Apkan et al. 2022; Pasricha et al. 2020). Thus, the total cost is $5.13–6.43 per child.

Therefore, the total cost of iron supplementation from the age of six to 59 months is about $46–58 per child if the supplementation program is repeated every six months for a total of nine times (three consecutive supplementation months followed by three months of intermission). This assumes that the full cost of promotion program and delivery is incurred all nine times, while in reality the cost may be less.

The benefit of iron supplementation is likely to be largest if the intervention is administered from the age of six months to mitigate potentially irreversible damage to the child's neuropsychological development during the first years of life. WHO recommends a supplemental dose of 10–12.5 mg and 30 mg of iron per day for children 6–23 months and 24–59 months of age respectively and administered daily for three consecutive months in a year (WHO 2016). Iron supplementation likely needs to be repeated multiple periods of times until the child reaches at least five years of age, as children of are most susceptible to neuropsychological developmental impairment from Pb in their early years of life.

5.4.1.4 Benefits of nutrition intervention

Iron supplementation is estimated to reduce mean BLLs in young children in Bangladesh by 0.8–1.2 µg/dL, and possibly by 2–3 µg/dL among children currently with BLLs of 10–15 µg/dL. This is estimated by applying the effect size of iron supplementation on BLL from the study in Morocco. The benefit of this reduction in mean BLL is an estimated gain of 0.4–0.6 IQ points. This gain is valued at 2 percent of lifetime income per IQ point for the percent of children expected to be in the labor force (see appendix G) resulting in an increase in lifetime income of Tk 21–32 thousand ($254–382) per child (table 5.21). Children with BLLs above the mean may experience larger benefits while children with BLLs below the mean may experience smaller benefits.

Table 5.21 Benefit of BLL reduction from iron supplementation

	Low	High	Remark
Mean BLL pre-intervention (μg/dL)	6.4	6.4	Mean BLL of children < 5 years estimated and projected from studies in Bangladesh
Change in mean BLL from iron supplementation	-0.80	20%	Effect size from Bouhouch et al. (2016)
Mean BLL post-intervention (μg/dL)	5.6	5.2	Calculated
IQ benefit (IQ points per child)	+0.4	+0.6	Based on Crump et al. (2013)
Benefit per IQ point (Tk, 2019)	86,143	86,143	Based on 2% lifetime income effect per IQ point
Rate of labor-force participation (15–64 years)	62%	62%	World Bank (2021)
Benefit per child (Tk, 2019)	21,363	32,045	Calculated
Benefit per child, $	254	382	Calculated

Source: World Bank.

Iron supplementation also provides a reduction in the prevalence of anemia. In an RCT in Bangladesh, the prevalence of anemia declined by nearly 50 percent from three months of 12.5 mg of iron supplementation given to eight-month-old infants (Pasricha et al. 2021). Also in Bangladesh, in a home fortification program with micronutrient powder for children 6–59 months of age in one-third of all upazilas, anemia declined by 38 percent (Ahmed et al. 2021). Likewise, a global systematic review and meta-analysis of RCTs found a 39 percent reduction in anemia among 4–23 months old children (Pasricha, Kalumba, and Biggs 2013).

Several studies have quantified the benefits of reduction in anemia in terms of disability-adjusted life years (DALYs) in low- and middle-income countries (Pasricha et al. 2020) including in Bangladesh (Ahmed et al. 2021; Apkan et al. 2022). DALYs are calculated using the disability weights from the GBD. This gives 0.025 DALYs per case of anemia averted for a one-year period using weighted average disability weights for mild, moderate, and severe anemia in Bangladesh.[55] Valuing a DALY at 1–3 times GDP per capita gives a benefit of Tk 900–2,700 ($11–32) in 2019 per child for anemia averted for one year, based on and the rate of anemia reduction in the study in Bangladesh by Pasricha et al. (2021). For an extended iron supplementation program for children from the age of 6 to 59 months, the benefit of reduction in anemia would be Tk 4,045–12,135 ($48–145) per child. This is substantially less than the benefit of the effect of iron supplementation on children's BLLs.

5.4.1.5 Benefit-cost ratio of nutrition intervention

The total benefits and costs of iron supplementation for children starting from the age of 6 months to the age of 59 months are presented in table 5.22. These benefits and costs give a benefit-cost ratio of 5.5–6.6 when counting only BLL reductions, and 6.6–9.1 when including the benefit of anemia reduction. Therefore, even though the effect of iron supplementation on children's BLLs is relatively modest, the benefit per taka spent is high.

Table 5.22 Benefits and costs of iron supplementation for children 6–59 months in Bangladesh

	Low end of range	High end of range
Benefit of BLL reduction (Tk)	21,363	32,045
Benefit of anemia reduction (Tk)	4,045	12,135
Cost of iron supplementation (Tk)	3,878	4,861
BCR (BLL reduction benefit)	5.5	6.6
BCR (anemia-reduction benefit)	1.0	2.5
BCR (BLL + anemia-reduction benefit)	6.6	9.1

Source: World Bank.

5.4.2 Cookware intervention

Studies of cookware made of recycled aluminum in Africa and Asia have found Pb released into food up to 260 μg per 250 mL serving (see chapter 2). A small study in Bangladesh found that one of four items tested released 2 μg of Pb per 250 mL serving while any Pb released from the other three was undetectable. Most recently the market survey by Pure Earth found that 59 percent of 27 sampled items of metallic cookware contained Pb concentrations above the reference level of 100 ppm, with a median and maximum Pb concentration of 186 and 8,186 ppm, respectively (Pure Earth 2023). The items have not been tested for leaching of Pb into food while cooking. Thus, studies are needed to assess the magnitude of lead contamination in food from recycled aluminum in Bangladesh.

To illustrate the magnitude of benefits and costs of addressing potential lead-contaminated cookware, the intervention assessed here is replacement of cookware made of lead-contaminated recycled aluminum with cookware made of a substitute material not contaminated with lead such as stainless steel. This intervention is targeted at households with young children and pregnant women to help prevent detrimental effects of Pb during the first years of life. The intervention also benefits older children as well as adults in the household.

5.4.2.1 Benefits of cookware intervention

The benefits of avoiding Pb exposure from aluminum cookware are largest for young children and if avoided from the point of pregnancy through the age of five years of the child to avoid potentially irreversible damage to the child's neuropsychological development during the first years of life.

The benefits to young children from avoiding Pb exposure from aluminum cookware for the first five years of life are presented in table 5.23 for 1–25 μg of Pb released per 250 mL food serving. Benefits are estimated based on the effect of Pb on BLLs and of BLLs on IQ and lifetime income. The effect of avoiding this exposure is a reduction in BLLs of 0.2–4.3 μg/dL. This is estimated using the Integrated Exposure Uptake Biokinetic (IEUBK) Model Version 2 developed by the USEPA. A reduction of this magnitude in BLLs is in turn expected to result in an increase in the children's IQ of 0.1–1.6 points. This gain in IQ is valued at 2 percent of lifetime income per IQ point for the percent of children expected to be in the labor force (see appendix G) resulting in an increase in lifetime income of Tk 5–88 thousand per child.

5.4.2.2 Benefit-cost ratio of cookware intervention

An alternative to aluminum cookware is stainless steel. A set of three pots made of stainless steel of sizes 2–5 liters costs around Tk 4,000.[56] This implies that the cost of switching to stainless steel is less than the benefit for a household expecting a child even if the household's current aluminum cookware only releases 1 μg of Pb per 250 mL food serving. For cookware that releases 2–25 μg of Pb the benefit-cost ratio (BCR) is 2.3–21.9. The BCRs would be even larger for households with two young children.

Table 5.23 Benefits to young children of avoiding Pb exposure from aluminum cookware

Pb from Cookware	μg/250 mL	1	2	5	10	25
BLL effect from cookware	μg/dL	0.19	0.37	0.92	1.80	4.29
IQ effect	IQ points	0.09	0.17	0.41	0.77	1.64
Benefit per IQ point	Tk	86,143	86,143	86,143	86,143	86,143
LFP rate (15–64 years) [a]	%	62%	62%	62%	62%	62%
Total benefit per child	Tk	4,667	9,142	21,927	41,120	87,602
Cost of stainless-steel cookware set	Tk	4,000	4,000	4,000	4,000	4,000
BCR		1.2	2.3	5.5	10.3	21.9

Source: World Bank estimates.
Note: [a] LFP = Labor-force participation.

The estimated benefits of avoiding exposure to Pb from aluminum cookware are conservative, since adults would also benefit from avoiding such exposure. However, estimating the benefits for adults requires a different model than the IEUBK Model as well as modeling the possibility of the lagged effects of lower BLLs on cardiovascular health improvements.

5.4.3 Interventions targeting used lead-acid battery (ULAB) recycling sites

Informal recycling of used lead-acid batteries (ULABs), including abandoned recycling sites, are major lead exposure "hot spots" in Bangladesh and many other low- and middle-income countries for workers and nearby residents (Ericson et al. 2016; Gottesfeld and Pokhrel 2011). Since 2011, the Toxic Sites Identification Program (TSIP) implemented by Pure Earth has collaborated with the Department of Geology of the University of Dhaka and the Department of Environment of Bangladesh in assessing 249 contaminated sites. As many as 175 of the sites are ULAB recycling and lead smelting sites located throughout the country (McCartor 2018). However, the total number of ULAB recycling and recharging facilities is substantially larger, reported in the range of 1,100 (World Bank 2018) to 12,200 (Ahmad et al. 2014). The latter figure is based a survey dating back to 2003–04 by the Bangladesh Bureau of Statistics (BBS).

Two abandoned adjacent ULAB recycling sites in Kathgora, Savar, in Dhaka Division, were rehabilitated in 2018. The sites had been in operation for six months before they were closed in 2016. Operations at the site had included battery case separation, washing and open-pit lead smelting. Rehabilitation included soil remediation (removal of topsoil) as well as removal of lead contaminated dust in nearby households, and community education. Lead concentrations in the soil were measured at 251 points around the sites. Pb concentrations reached over 100,000 mg/kg (ppm) with a mean of 1,400 mg/kg. Concentrations declined with distance from the abandoned recycling and smelting locations. The mean concentration declined to 50 mg/kg after soil remediation (Chowdhury et al. 2021; McCartor and Nash 2018). The cost of the rehabilitation of the sites was $40,300. This included community education ($1,200), soil remediation ($37,500), and household lead dust removal and cleaning ($1,600) (Chowdhury et al. 2021).

5.4.3.1 Benefits of interventions targeting ULAB recycling sites

Rehabilitating ULAB recycling sites is likely to benefit children more than adults, since children are often more exposed to Pb in soil and dust through play activities. The lead-contaminated soil and dust at the two abandoned sites and in adjacent homes is likely to have caused irreversible damage to the neuropsychological development of many of the children living near the site. Rehabilitation of the site allows future generations of children to grow up in a cleaner environment. Benefits are estimated accordingly for an annual birth cohort of six children per year for the next twenty years. Children's mean BLL changed from 22.6 to 14.8 µg/dL from the rehabilitation project (Chowdhury et al. 2021). Future children are on average expected to gain 1.33 IQ points from this improvement in BLL. This gain is valued at 2 percent of lifetime income per IQ point for the percent of children expected to be in the labor force (see appendix G) with the annual birth cohort of six children gaining Tk 435,000 ($5,173) in lifetime income (table 5.24). This annual gain in lifetime income is projected to grow at a rate of 2.5 percent per year for each subsequent birth cohort over the twenty-year assessment period, discounted at 5 percent.

Table 5.24 Benefits of the rehabilitation of an abandoned ULAB recycling site in Kathgora, Bangladesh

Pre-intervention BLL (µg/dL)	22.6	Chowdhury et al. (2021)
Post-intervention BLL (µg/dL)	14.8	
IQ points gained per child	1.33	Based on Crump et al. (2013)
Annual birth cohort	6.1	Calculated based on children population
Benefit per IQ point, Tk	86,143	Based on 2% lifetime income effect per IQ point [a]
Rate of labor-force participation (15–64 years)	62%	World Bank (2023)
Total annual benefit, Tk thousands	435	Calculated
Total annual benefit, $	5,173	Calculated

Source: World Bank.
Note: [a] Lifetime income is calculated using an annual growth rate of real income of 2.5% from age 18 to 65 years and an annual discount rate of 5 percent.

5.4.3.2 Benefit-cost ratio of intervention targeting ULAB recycling site

Over a period of twenty years from the rehabilitation project's completion, the discounted present value of income benefit totals Tk 6.65 million ($79,129). The benefit-cost ratio (BCR) for the site rehabilitation is 1.96, indicating that benefits are nearly twice the cost). This may be considered conservative in so far that other benefits to children, as well as to some extent to adults, are not quantified (table 5.25.

Table 5.25 Present value of total benefits and costs of site rehabilitation

	Tk, millions (2019)	$ (2019)
Total benefits	6.65	79,129
Total costs	3.39	40,300
BCR	1.96	1.96

Source: World Bank.
Note: Benefits over 20 years discounted at a rate of 5 percent per year.

A systematic review of the evidence on the effectiveness of remediation of lead-contaminated soil at five sites in high-income countries found a much smaller effect on BLLs than the project in Bangladesh (Dobrescu et al. 2022). The sources of soil lead contamination were nearby mines and/or smelters and lead-based paint. Soil remediation involved removal of the upper layer of soil and replacing with clean soil. Two studies also included interior dust abatement and/or lead-based paint interventions. However, an assessment of remediation of lead contaminated sites in six middle-income countries found declines in mean BLLs of 33–90 percent while only 6 percent at a site in a seventh country. BCRs ranged from 1.7 to 50 using the same methodology and valuation of benefits as for Bangladesh (World Bank, forthcoming). The BCRs very much depend on the effect of remediation on BLLs, the size of exposed population, income level at the time of site remediation, and cost of remediation per exposed population.

5.4.4 Conclusions on interventions to mitigate and prevent lead exposure

BLLs in Bangladesh remain at levels that cause serious health effects in children and adults. Tens of studies have documented some of the sources of Pb pollution and population exposures. Well-recognized sources of exposure include ULAB recycling and occupational exposures. Pb in turmeric has also been a major concern but appears to have been addressed. However, concerns have increased over Pb and other heavy metal contamination of the food supply, such as rice, vegetables, and fish. While studies are insufficient to determine Pb concentrations in food consumed by the majority of the population, the analysis in this chapter indicates that Pb in food may be a major cause of elevated BLLs in the general population. An undetermined share of Pb in rice, vegetables and culture fish may be from chemical fertilizers and commercial fish feed, as indicated by some studies. The chapter also highlights that cookware made from recycled aluminum may be a major source of Pb exposure for at least some of the population.

While the challenges of Pb pollution and population exposure will take time to solve, there are immediate actions that can be taken for which benefits by far exceed the costs as evidenced by the benefit-cost analysis in this chapter (table 5.26).

Table 5.26 Benefit-cost ratio (BCR) of three interventions to mitigate and prevent Pb exposure

	BCR
Iron supplementation for children 6–59 months	6.6–9.1
Replacement of aluminum cookware contaminated with Pb	1.2–21.9
Rehabilitation of an abandoned ULAB recycling site in Kathgora	1.9

Source: World Bank.

However, a comprehensive intersectoral and interdisciplinary approach is required for optimal mitigation and prevention of Pb exposure. The priority is the following set of measurement studies: (a) undertake nationally representative BLL measurements in children and adults as well as of populations in hot spots; (b) undertake nationally representative Pb measurements in rice and vegetables in dry and wet seasons in urban and rural wholesale markets and own produce in rural areas; (c) undertake nationally representative Pb measurements of rice and vegetables in agricultural fields in dry and wet season, and of chemical fertilizers and irrigation water used in these fields; (d) undertake pilot Pb measurements of agricultural residues used for household energy, as well as measure household Pb air pollution, to assess Pb air pollution concerns; (e) undertake nationally representative Pb measurements in capture and culture fish at wholesale and local markets; (f) undertake nationally representative Pb measurements in culture fish and fish feed at fish farms; (g) undertake a sector study of cookware made from recycled aluminum to verify the extent of recycling, sources of recycled aluminum used for making cookware, and (h) undertake measurements of Pb leached into food while cooking.

Once these measurement studies are implemented or underway for implementation, the next priority actions are the following: (a) identify potential interventions for mitigation and prevention of Pb contamination of the food supply, including phytoremediation of Pb and heavy metals in soil and water; (b) set up a comprehensive Pb monitoring and surveillance system; (c) institutionalize the handling of lead-poisoning cases; (d) develop appropriate regulations for the main sources of Pb pollution; (e) develop Guidelines and Manual for Toxic-Site Remediation as a basis for support to a government Plan for Remediating Toxics; (f) Set up a government-run Toxic-Sites Database; (g) develop and enforce regulations for the ULAB recycling sector; and (h) focus on home-based assessment in determining the risk of Pb exposure.

5.5 Benefits and costs of improved WASH interventions

This section assesses the benefits and costs of 12 drinking water, sanitation, and hygiene (WASH) interventions: six drinking-water interventions, two sanitation interventions, and four handwashing-with-soap interventions. Quantified benefits of the interventions are health improvements and potential time savings. Both direct health benefits in terms of averted illness and mortality from diarrheal disease, and indirect health benefits in terms of averted child mortality through improved nutritional status from averted diarrheal disease are discussed here. The main literature utilized to assess direct health benefits of interventions is an analysis of worldwide studies by Wolf et al. (2018) who present relative risks (RRs) of diarrheal disease associated with various types of household drinking water, sanitation, and handwashing in low- and middle-income countries. Percentage reduction in diarrheal deaths from WASH interventions is considered the same as the percentage reduction in diarrheal disease, assuming a constant fatality rate per case of diarrheal illness. Olofin et al. (2013) and Fewtrell et al. (2007) are applied to estimate indirect health benefits of interventions. Olofin et al. provide a methodology for estimating child mortality associated with poor nutritional status of children, and Fewtrell et al. (2007) provide guidance on the magnitude of effect of diarrheal disease in early childhood on children's nutritional status (see appendix F).

The assessed interventions in this section are household-level interventions. Additional interventions that may be considered are community-level interventions such as high-quality piped water supply and community-level safe management of fecal sludge from household sanitation facilities.

5.5.1 Drinking-water interventions

Over 98 percent of the population in Bangladesh used an improved water source for drinking in 2019 according to the nationally representative Bangladesh Multiple Indicator Cluster Survey (MICS) 2019 (BBS/UNICEF 2019). However, 40 percent of the household population had E.coli in their source water and as many as 82 percent had E.coli in their actual drinking water. This points to the importance of safe handling and storage of drinking water, as well as improving quality of piped water supply. It also points to the potential role that household point-of-use treatment (POUT) of drinking water can have in improving the safety of drinking water from microbiological pollution. Only 10 percent of the population currently practice POUT of drinking water in Bangladesh (BBS/UNICEF 2019).

The drinking-water interventions assessed here are six household POUTs: (a) solar disinfection of drinking water; (b) ceramic filtering of drinking water; (c) boiling of drinking water using agricultural residues as energy for boiling; (d) boiling of drinking water using fuelwood as energy for boiling; (e) boiling of drinking water using LPG as energy for boiling; and (f) boiling of drinking water using electricity as energy for boiling.

5.5.1.1 Cost of drinking-water interventions

Solar disinfection of drinking water: Solar disinfection has been demonstrated to be effective for eliminating microbial pathogens in drinking water (Clasen 2009; Clasen et al. 2015). Disinfection of water is based on the combined effect of thermal heating and UV radiation (McGuigen et al. 2012). A common method of solar disinfection is placing 1–2 liters transparent bottles with water (for example, beverage bottles) in the sun for about six hours in locations with high solar radiation and up to two days under cloudy conditions. The disinfected water should be kept in bottles until consumption to avoid recontamination (Clasen 2009). All that is required for this method of drinking-water treatment is transparent plastic or glass bottles; thus, no significant initial capital cost is incurred. However, the method involves some incremental time for filling bottles with water, placing bottles under sunlight, collecting and cleaning bottles, here assumed to be five minutes per household per day valued at 50 percent of average female rural hourly wage rate.

Ceramic filtering of drinking water: Ceramic filters can be simple and effective for removing pathogens in water. Devices consist of a porous ceramic filter coated with colloidal silver. A ceramic filtering device can fulfill a household's need for drinking water and produce 20–30 liters of purified water per day. It is easy to clean, light weight, portable, and available at various costs and durability. A simply gravity-based system with water storage container may cost Tk 1,500. A useful life of one year is assumed to be conservative.

Boiling of drinking water: Boiling and filtering are the two most prevalent forms of household treatment of drinking water in Bangladesh. Cost of boiling depends largely on the type of fuel used for boiling, ranging from Tk 1,171 per household per year for households using self-collected on-farm agricultural residues as energy for boiling to Tk 2,819 for households using LPG (table 5.27). Cost is estimated based on quantity of drinking water, energy required to boil water, stove efficiency, energy content of fuels, and cost of energy per kg or kWh. Cost of using agricultural residues is the time spent on collection, assumed to be five minutes per household per day valued at 50 percent of average female rural hourly wage rate. Average fuel wood price in Bangladesh is applied for calculating the cost of boiling water with wood. The cost applied for LPG is a multiyear average world price including transportation and distribution. Cost of boiling water with electricity depends on household electricity consumption as electricity tariffs increase with consumption. A tariff rate of Tk 6.00 per kWh is applied reflecting a midrange level of consumption.

Table 5.27 Cost of boiling drinking water

	Residues	Wood	LPG	Electricity
Quantity of water for boiling (liters per person per day)	1.5	1.5	1.5	1.5
Energy requirement for heating of water (Joules/liter/1 degree Celsius)	4,200	4,200	4,200	4,200
Energy content of fuel (MJ/kg) [a]	7.5	15.1	47.7	—
Stove efficiency for boiling water (%)	12	15	50	60
Energy requirement for boiling water (per household per year)	879 kg	349 kg	33 kg	366 kWh
Cost of energy (Tk)	n.a.	5.60 per kg b	85 per kg c	6.00 per kWh
Cost of boiling water (Tk per household per year)	1,171	1,956	2,819	2,197

Source: World Bank.
Note: a SREDA 2020. b BBS 2021. c Economic cost exclusive of taxes. — = Not available; n.a = Not applicable.

Annualized costs of the household POUT of drinking-water interventions are presented in table 5.28. Solar disinfection has the lowest cost followed by boiling drinking water using agricultural residues as energy for boiling. On-farm agricultural residues are free but have a recurrent cost in terms of time spent on residue collection (see below). The cost of boiling drinking water using LPG is most expensive followed by the cost of using electricity. The cost of using ceramic filtering and boiling using fuelwood is similar but depends critically on the cost of the filter and durability.

The incremental time spent by the household on practicing any one of these methods for treating drinking water is a significant cost component. An incremental time use of five minutes per household per day for all treatment options is applied. Time is valued at 50 percent of average female rural hourly wage rate for boiling with agricultural residues or fuelwood and average national female wage rate for solar disinfection and boiling with LPG or electricity. A promotion program to encourage households to adopt one of the interventions for treating drinking water is an additional cost. The program is assumed to be effective for five years. The program cost is Tk 1,000 per household, annualized with a five percent discount rate.

Table 5.28 Annualized cost of household POUT of drinking water | *Tk per household per year*

	Solar disinfection	Ceramic filter	Boiling of water (agricultural residues)	Boiling of water (wood)	Boiling of water (LPG)	Boiling of water (electricity)
Annualized capital cost	n.a.	1,500	n.a.	n.a.	n.a.	n.a.
Annual cost of boiling water	n.a.	n.a.	1,171	1,956	2,819	2,197
Annual cost of incremental time used for water treatment	1,672	1,672	1,171	1,171	1,672	1,672
Annualized cost of promotion program	231	231	231	231	231	231
Total annualized cost	**1,903**	**3,403**	**2,573**	**3,358**	**4,722**	**4,100**

Source: World Bank.
Note: n.a. = Not applicable.

5.5.1.2 Benefits of drinking-water interventions

The health benefits of interventions assessed here pertain to morbidity and mortality from diarrheal disease, intestinal infections (typhoid/paratyphoid), and infectious-disease mortality associated with child underweight in part caused by repeated diarrheal disease in early childhood. Estimating the reduction in these disease burdens from interventions requires knowledge of the risk of disease after receiving an intervention relative to the risk before receiving the intervention. The relative risks from a meta-analysis of studies of POUT are reported in table 5.29 for households with improved drinking-water source, which over 98 of the population in Bangladesh has. These relative risks indicate that POUT provides 24–56 percent disease reduction.

A disease reduction of 24 percent is applied for solar disinfection of drinking water and 52 percent for ceramic filtering. The latter is the midpoint of disease reduction for filtering with and without safe water storage after treatment. This rate of disease reduction is also applied to boiling of drinking water (Prüss-Üstün et al. 2019).

Table 5.29 Relative risk (RR) of diarrheal disease and mortality for household point-of-use treatment (POUT) of drinking water

Solar disinfection	Filtering	Filtering and safe storage
0.76	0.55	0.44

Source: Wolf et al. 2018.

An estimated 22,000 deaths and 500 million days with diarrheal disease can be avoided each year if all households adopt regular POUT of drinking water using ceramic filtering or boiling. A little less than half of these health effects can be avoided if solar disinfection of drinking water is adopted. The value of health benefits per beneficiary household per year is presented in table 5.30 using the methodology in appendixes H and I. Benefits in terms of reduction in infectious diseases are the same for ceramic filtering and boiling of drinking water because the same relative risk reduction in infectious disease is applied. However, using agricultural residues and fuelwood for boiling drinking water causes household air pollution.

The marginal health damage cost from the use of solid fuels for cooking in Bangladesh is estimated at Tk 52,476 per household per year in 2026—the midpoint of the intervention time horizon until 2030. Agricultural residue and fuelwood requirement for boiling drinking water is estimated at about 25 percent of fuel used for cooking based on estimated energy requirement for boiling in table 5.27. Thus, the health damage cost or negative health benefit is Tk 10,102 per household per year.[57] Therefore, net health benefits are largest for ceramic filtering and boiling of drinking water using LPG and electricity. Net health benefits are smallest for boiling water with agricultural residues or wood due to health effects of household air pollution and for solar disinfection due to smaller percent reduction in infectious disease.

Table 5.30 Benefits of drinking-water interventions *Tk per household per year*

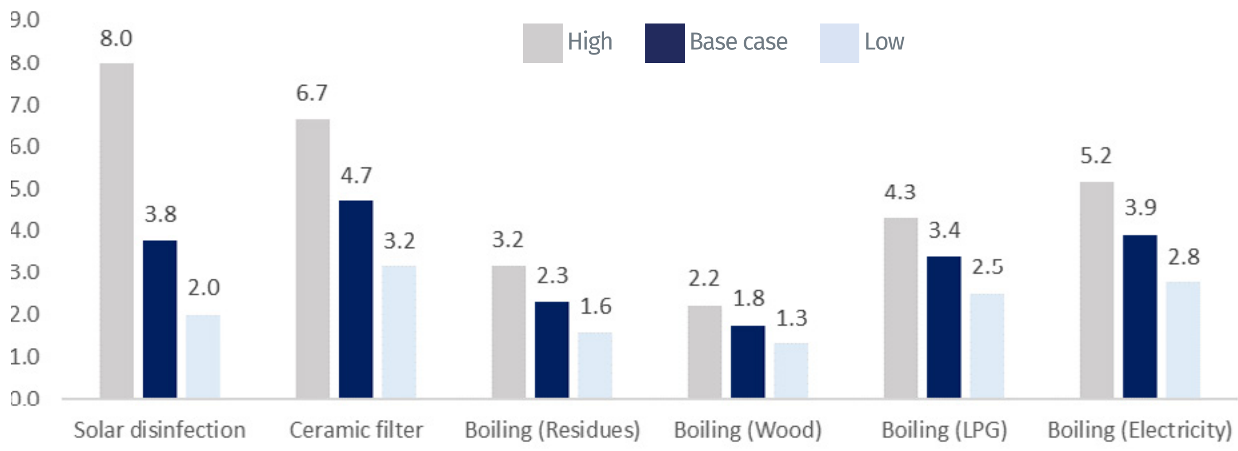
	Solar disinfection	Ceramic filter	Boiling of water (agricultural residues)	Boiling of water (wood)	Boiling of water (LPG)	Boiling of water (electricity)
Annual infectious-disease benefits	7,178	16,011	16,011	16,011	16,011	16,011
Annual health damage from household air pollution	n.a.	n.a.	-10,102	-10,102	n.a.	n.a.
Annual net health benefits	7,178	16,011	5,909	5,909	16,011	16,011

Source: World Bank.
Note: n.a. = Not applicable.

5.5.1.3 Benefit-cost ratios of drinking-water interventions

The BCRs of the interventions range from 1.8 to 4.7 in the base-case (figure 5.5). The base case reflects that five minutes are spent on water treatment per household per day. The cost of this time use accounts for 35 to 88 percent of total cost of treatment. The BCRs are therefore sensitive to the amount of time spent on treatment. BCRs are 1.3 to 2.8 if ten minutes are spent per day (low-case) and 2.2 to 8.0 if only two minutes are spent per day (high-case). The BCR is smallest for boiling drinking water with fuelwood or agricultural residues because of the damage to health from the household air pollution that is caused by these fuels. BCRs are largest for ceramic filter, boiling drinking water with electricity, and solar disinfection. The advantage of ceramic filtering is larger health benefits than for solar disinfection while the disadvantage is the cost of the filter. The BCR for boiling water using LPG is smaller than for boiling with electricity.

Figure 5.5 Benefit-cost ratios (BCRs) of household POUT drinking-water interventions



Source: World Bank estimates.

5.5.2 Sanitation interventions

About 15 percent of the population in Bangladesh relied on unimproved sanitation in 2019, and 20 percent of the population shared otherwise improved sanitation facilities with other households according to the Bangladesh MICS 2019 household survey (BBS/UNICEF 2019). The most common type of improved sanitation facility is flush or pour-flush toilet connected to a septic tank or pit. Therefore, the household sanitation interventions assessed here are the following: (a) Installation of non-shared pour-flush/flush toilet facility with septic tank to households currently relying on unimproved sanitation facilities; and (b) Installation of non-shared pour-flush/flush toilet facility with septic tank to households currently sharing improved sanitation facilities with other households.

Interventions should fulfill the "safely managed sanitation" criteria defined as the use of an improved sanitation facility not shared with other households and where excreta are "safely disposed on-site" or are transported and "treated off-site." Safely disposed on-site means excreta are disposed in septic tanks with appropriate leach fields or in latrine pits that are left undisturbed when full. Safely treated off-site means either excreta are transported by sewer lines to wastewater treatment plants or emptied from septic tanks/pits and treated off-site at facilities designed for fecal sludge (UNICEF/WHO 2019).

5.5.2.1 Cost of sanitation interventions

The cost of the household sanitation interventions includes the initial capital cost of the sanitation facility, annual operation and maintenance (O&M), and regular cleaning of the facility.

The government of Bangladesh recommends toilets with sanitary offset pit(s) (UNICEF 2020) to facilitate safe sanitation management in line with the Sustainable Development Goals. The cost of a pour-flush toilet with a single sanitary offset pit made of concrete rings and slab and a durable superstructure is estimated at Tk 8,000–14,000 (UNICEF 2020). A midpoint of Tk 11,000 is applied in this benefit-cost assessment. The assumed useful life is 15 years. The annual discount rate is 5 percent. Cleaning of the sanitation facility is assumed to take 30 minutes per week more than the time spent on cleaning the household's pre-intervention unimproved sanitation facility. Time is valued at 50 percent of average wage rates. Annual operations and maintenance (O&M) cost is 5 percent of initial capital cost. A promotion program to encourage households to adopt the interventions is an additional cost. The program cost is Tk 1,000 per household, annualized over the useful life of the sanitation facility. Cost of cleaning constitutes 51 percent, capital cost 30 percent, O&M 16 percent, and promotion program 3 percent of total annualized cost (table 5.31).

Table 5.31 Cost of household sanitation | *Tk per household per year*

Annualized capital cost	1,060	Initial capital cost is Tk 11,000
Annual O&M cost	550	5% of capital cost
Annual cost of cleaning	1,787	30 minutes per household per week
Annualized cost of promotion program	96	Annualization of Tk 1,000 per household
Total annualized cost	**3,493**	**Per household**

Source: World Bank.

For households that share a sanitation facility with other households, the cost per beneficiary household of the sanitation intervention is less than reported in table 5.31. Nearly 90 percent of the households that share an improved sanitation facility with other households share the facility with five or less households (BBS/UNICEF 2019). Assuming an average of three households per shared facility implies that two new facilities need to be constructed per three households. Since all three households benefit from the construction, the average cost per beneficiary household is Tk 2,361.[58]

5.5.2.1 Benefits of sanitation interventions

The benefits of improved and safely managed sanitation include health improvements, environmental benefits, intangible benefits such as status and comfort, and potential time savings benefits. There are both direct household benefits and wider community benefits such as reduced fecal contamination of land and water bodies, with reduced risk of contamination of drinking-water sources and other pathways of human exposure.

The benefits quantified in this assessment are limited to health and potential time savings benefits, because environmental and intangible benefits are difficult to quantify. The health benefits of the interventions pertain to diarrheal disease and intestinal infections (typhoid/paratyphoid), and infectious disease mortality associated with child underweight in part caused by repeated diarrheal disease in early childhood.

Estimating the reductions in these disease burdens from interventions requires knowledge of the risk of disease before and after receiving an intervention. The relative risks from a meta-analysis of studies by Wolf et al. (2018) of improved non-shared household sanitation relative to unimproved sanitation is reported in table 5.32. The analysis found a larger reduction in risk of diarrheal disease from improved non-shared sanitation if improved sanitation included sewage connection—that is, 40 percent versus 16 percent. The analysis also found a larger reduction in disease risk for improved sanitation provided in communities with high sanitation coverage—that is, 45 percent versus 24 percent.

Table 5.32 Relative risk (RR) of diarrheal disease and mortality for improved sanitation

	RR
Unimproved sanitation	1.00
Improved (non-shared) sanitation without sewage connection	0.84
Improved (non-shared) sanitation with sewage connection	0.60
Improved (non-shared) sanitation (< 75% community sanitation coverage)	0.76
Improved (non-shared) sanitation (> 75% community sanitation coverage)	0.55

Source: Wolf et al. 2018.

A relative risk of 0.55, with 45 percent disease reduction, is applied here for households that benefit from the intervention "installation of non-shared pour-flush/flush toilet facility with septic tank to households currently relying on unimproved sanitation facilities." The relative risk of 0.55 reflects the comparatively high community-sanitation coverage in Bangladesh. For households with improved sanitation but sharing the facility with other households, a lower disease reduction of 16 percent is applied for receiving non-shared facility with septic tank (table 5.33).

Table 5.33 Relative risk (RR) of diarrheal disease and mortality for sanitation interventions

	Disease reduction (%)
Improved non-shared safely managed sanitation for households currently with unimproved sanitation	45
Improved non-shared safely managed sanitation for households currently sharing improved sanitation with other households	16

Source: World Bank.

An estimated 6,230 deaths and 155 million days with diarrheal disease can be avoided each year if all households adopt the sanitation interventions—that is, by the 15 percent of the population currently with unimproved sanitation and the 20 percent currently sharing sanitation facilities with other households.

The valuation of the health benefits of interventions per household per year is estimated using the methodology in appendixes H and I. The health benefits for households currently having unimproved sanitation are over four times larger than for households sharing sanitation facilities with other households (table 5.34).

Times savings benefits may be expected for the households that adopt the intervention "installation of non-shared pour-flush/flush toilet facility with septic tank to households currently sharing improved sanitation facilities with other households." These households will have shorter access time to their new facility both in terms of distance and waiting time. It is here assumed that the time saving is 5 minutes per person. Time savings are valued at 50 percent of average wage rates for individuals 15+ years of age and are on average almost as large as the health benefits (table 5.34).

Table 5.34 Benefits of household sanitation interventions | *Tk per beneficiary household per year*

	Improved non-shared from unimproved sanitation	Improved non-shared from improved shared sanitation
Annual health benefits	20,509	4,774
Time savings benefits	0	4,254
Total benefits	**20,509**	**9,028**

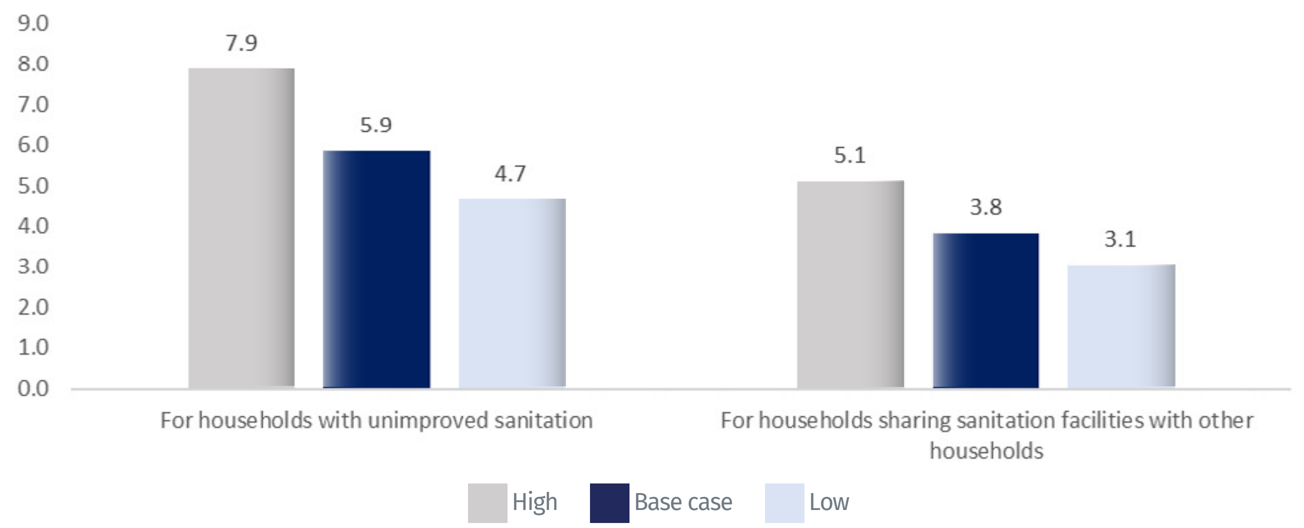
Source: World Bank.

5.5.2.3 Benefit-cost ratios of sanitation interventions

The BCRs of sanitation interventions range from 3.8 to 5.9 in the base-case (figure 5.6). The base case reflects that an additional 30 minutes are spent on toilet cleaning per household per week to keep it in a sanitary and safe condition. The cost of this time use accounts for 51 percent of total cost. The BCRs are therefore sensitive to the amount of time spent on cleaning. BCRs are 3.1 to 4.7 if 45 minutes are needed per week to keep it in a sanitary condition (low-case) and 5.1 to 7.9 if only 15 minutes are needed (high-case). The BCR is largest for the adoption of improved non-shared and safely managed sanitation facilities by households with unimproved sanitation. The BCR for households sharing sanitation facilities with others is smaller due to smaller benefits per household but indicates that benefits are 3.1 to 5.1 times larger than cost.

The BCR for improved non-shared sanitation for households currently sharing facilities with other households is also sensitive to the time benefits of easier access to facility. If time savings are 2 instead of 5 minutes per person per day, the BCR is 2.7 instead of 3.8.

Figure 5.6 Benefit-cost ratios (BCRs) of improved non-shared sanitation



Source: World Bank estimates.

5.5.3 Hygiene interventions

Handwashing with soap and water is found to be the most effective hygiene intervention in reducing diarrheal disease (Cairncross et al. 2010; Ejemot-Nwadiaro et al. 2021; Wolf et al. 2018) and acute respiratory infections (Rabie and Curtis 2006). The Bangladesh MICS 2019 (BBS/UNICEF 2019) reports that 75 percent of the population had access to handwashing with soap and water on household premises while 25 percent did not have a place with such items. However, this does not mean that everyone with a handwashing facility washes hands adequately at critical junctures. Having a handwashing facility is hence converted to an estimate of actual handwashing with soap based on an analysis of the association between having a facility and observed handwashing with soap. This conversion indicates that 47 percent of the population practices regular handwashing at critical junctures in Bangladesh (Prüss-Üstün et al. 2019).

The benefits and costs are assessed for an intervention that is delivered by implementing a promotion program for handwashing with soap at critical junctures. Benefits and costs are assessed for four groups of households: (a) all households; (b) households with children under five years of age; (c) households without children under five; and (d) only the caretakers of children under five and the children under five in the household. Children under five and the population five years and older are differentiated, since these two population groups have very different disease and mortality rates.

5.5.3.1 Cost of hygiene interventions

Handwashing with soap has multiple recurrent costs. These are the use of water for handwashing, soap, and the value of time spent on handwashing. For individuals five years and older, resource use is 3 liters of water per person per day, 12 bars of soap (100 gm each) per person per year, and three minutes spent on handwashing per person per day. Resource use is double for caretakers of children under five, as caretakers perform handwashing for themselves and at least one child (table 5.35).

Table 5.35 Recurrent resources spent on handwashing with soap

	Persons five years or older	Caretaker of child under five years
Water for handwashing (liters per person per day)	3	6
Soap consumption (bars per person per year)	12	24
Time spent on handwashing (minutes per person per day)	3	6

Source: World Bank estimates.

The annualized costs of handwashing with soap are presented in table 5.36. The applied cost of water is Tk 25 per m^3 for households with piped water into the dwelling and Tk 248 per m^3 for households with water in the yard or outside yard. The cost of the latter reflects the value of time spent on collecting and bringing water into the dwelling or to a place convenient for handwashing.[59] Cost of soap consumption is calculated at Tk 35 per bar of soap. Time spent on handwashing is valued at 50 percent of average wage rate.

The intervention includes a handwashing facility—a purpose-built 20-liter drum with tap, basin, and stand—at a cost of Tk 1,400 per facility (Ross et al. 2021). The cost is annualized over five years at an annual discount rate of 5 percent. The total cost of the intervention will be 5–10 percent lower for households that already have a handwashing facility. The intervention also includes an initial handwashing promotion program costing Tk 1,000 per household also annualized over five years.

It is assumed that households with children under five years of age have one child of this age. The annualized cost per household for the first three household scenarios is the same. In the last household scenario, the promotion program only targets caretakers of children under five. Therefore, the recurrent cost is only for a caretaker and child and not for other household members. The annualized cost per household is a little less than half the cost for the first three-household scenarios.

Time spent on handwashing constitutes 60 percent of total annualized cost. Soap consumption is the second largest cost component followed by the cost of incremental water consumption.

Table 5.36 Annualized cost of handwashing with soap | *Tk per household per year*

	(1) All households	(2) Households with children under five	(3) Households without children under five	(4) Caretaker and children under five only)
Cost of water for handwashing	1,114	1,114	1,114	518
Cost of soap consumption	1,806	1,806	1,806	840
Cost of time spent on handwashing	5,393	5,393	5,393	2,508
Annualized cost of handwashing facility	323	323	323	323
Annualized cost of promotion program	231	231	231	231
Total annualized cost	**8,867**	**8,867**	**8,867**	**4,421**

Source: World Bank estimates.

5.5.3.2 Benefits of hygiene interventions

Handwashing with soap can reduce diarrheal disease and ALRIs. Estimating the reductions in these disease burdens requires knowing the risk of disease after adopting an intervention relative to before the intervention. Reviews of studies have found diarrheal disease reduction of 30 percent (Ejemot-Nwadiaro et al. 2021) and ALRI disease reduction of 26 percent (Rabie and Curtis 2006) from handwashing with soap at critical junctures such as before food preparation and eating and feeding a child, and after going to the toilet.

An estimated 13,500 deaths and 215 million days with diarrheal disease and ALRI can be avoided each year if all households adopt handwashing with soap. Currently, 53 percent of the population is not practicing adequate handwashing. These potential health benefits are estimated using the potential impact fraction (PIF) formula in annex N and the disease-reduction rates above. The valuation of health benefits per household per year is estimated using methodology in appendixes H and I. Benefits per household are substantially higher for households with children under five than for households without children under five. Benefits would be even greater for households with more than one child under five. For the last scenario, with the promotion program only targeting caretakers and children under five, the household benefits are lower as only two individuals benefit from the program (table 5.37).

Table 5.37 Benefits of handwashing with soap | ***Tk per household per year***

	(1) All households	(2) Households with children under five	(3) Households without children under five	(4) Caretaker and children under five only
Annual health benefits	16,869	21,127	14,253	13,503

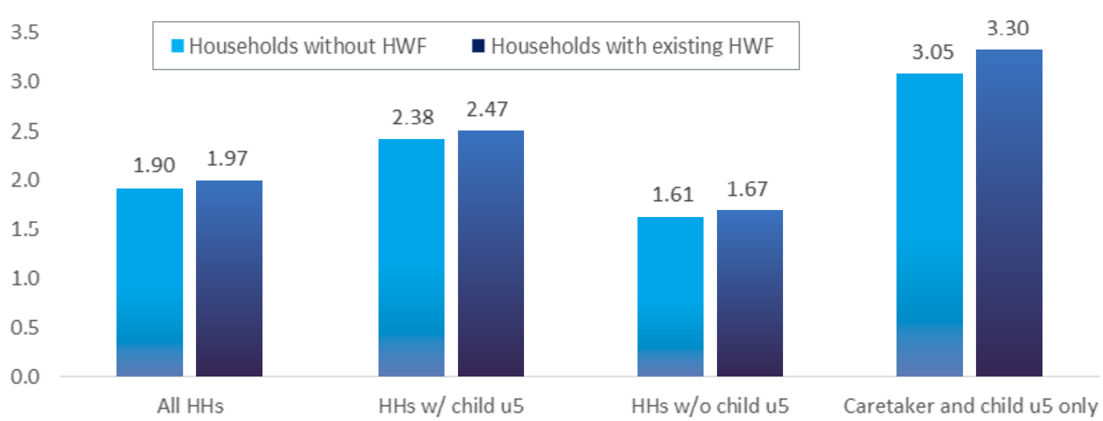
Source: World Bank estimates.

5.5.3.3 Benefit-cost ratios of hygiene interventions

The BCRs of the handwashing with soap interventions range from 1.6 to 3.3 (figure 5.7). The BCR is largest for a promotion program that targets caretakers of children under five years of age (caretaker plus child only). For programs that target all household members, BCR is substantially higher for households with children under five. BCRs are slightly larger for households that already have a handwashing facility (HWF). The BCRs will only be slightly lower if only a portion of targeted households, or only a portion of household members responds to the handwashing promotion program because all costs and benefits are proportional to the number of households or individuals responding to the intervention, except for the cost of the promotion program which is a very small fraction of total cost.

The BCRs are sensitive to the incremental time spent on handwashing due to its large share of total cost. However, the BCR exceeds one (that is, benefits exceed cost) for time use up to 6 minutes per person per day in all scenarios in figure 5.7, and up to 14 minutes for caretaker plus child only.

Figure 5.7 Benefit-cost ratios (BCRs) of handwashing with soap at critical junctures, 2019



Source: World Bank estimates.
Note: HHs = Households; w/ = with; w/o = without; u5 = under five years of age; HWF = Handwashing facility.

5.5.4 Conclusions on improved WASH interventions

The drinking water, sanitation, and hygiene interventions assessed in this report have the potential to avert nearly 34,000 deaths per year if fully implemented and adopted. The largest potential is from household POUT of drinking water followed by handwashing with soap (table 5.38).

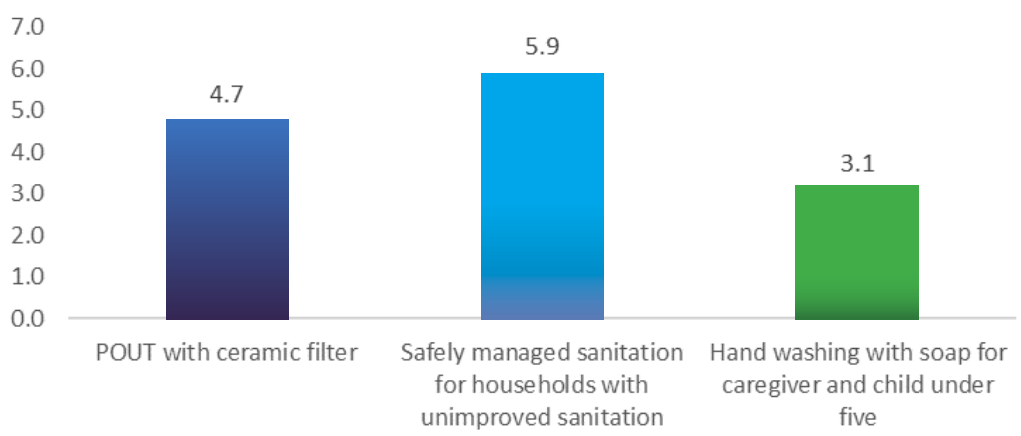
Table 5.38 Summary of benefit-cost assessment of interventions

Interventions	BCRs	Population in need of intervention (%)	Potential averted deaths per year
Household POUT of drinking water	1.8–4.7	90	21,783
Safely managed non-shared household sanitation	2.1–6.0	35	6,232
Handwashing with soap	1.6–3.3	53	13,515
Total			**33,838** [a]

Source: World Bank estimates.
Note: [a] "Total" is estimated using joint attributable fraction formula.

The interventions with the highest BCRs are household POUT with ceramic filter, safely managed improved non-shared sanitation for households currently having unimproved sanitation, and promotion of handwashing with soap targeting caregivers of children under five years of age (figure 5.8). Therefore, these interventions have the highest priority for implementation. However, their implementation should be followed by safely managed improved non-shared sanitation for households currently sharing sanitation with other households, and promotion of handwashing with soap to all household members as these interventions also have BCRs above 1, meaning that benefits exceed costs of intervention.

Figure 5.8 Interventions with the highest benefit-cost ratios (BCRs)



Source: World Bank estimates.

5.6 Benefits and costs of mitigating arsenic in drinking water

Testing of drinking water continues to confirm that arsenic contamination of drinking water remains a health concern in Bangladesh (BBS/UNICEF 2019). Annual deaths from population exposure to arsenic in drinking water are estimated at over 40,000 in 2019 along with 1.7 billion days lived with chronic illness.

Arsenic contamination is far more prevalent in shallow tube wells than in deep tube wells. However, some deep tube wells, especially in Sylhet division, are also contaminated (BBS/UNICEF 2011). Therefore, an intervention to avoid arsenic exposure is the provision of deep tube wells in locations where deep tube wells will not be contaminated. Ponds with sand filter may be an option in locations where deep tube wells are likely to be contaminated with arsenic. Even tube wells with intermediate depth are often free from arsenic in locations with arsenic in shallow tube wells (Jamil et al. 2019). A third intervention is household point-of-use (POU) filtering, such as the SONO filter developed in Bangladesh that uses iron and sand filtration. The SONO filter has been demonstrated to effectively remove arsenic in drinking water (Neumann et al. 2013). However, wide adoption and sustained use of filters have been challenging to achieve (Kundu, Mol, and Gupta 2016; Sanchez et al. 2016). Three arsenic mitigation interventions are assessed: (a) deep tube wells; (b) community pond sand filter; and (c) household point-of-use (POU) filtering of drinking water.

These interventions would be targeted at the nearly 17 percent of households in Bangladesh with more than 10 µg/L of arsenic in their drinking water (BBS/UNICEF 2019). Large-scale and continued arsenic testing of groundwater would form a solid basis for the interventions and would provide its own benefits in encouraging households to take actions to reduce exposure to contaminated wells (Jamil et al. 2019).

5.6.1 Cost of arsenic-mitigation interventions

The costs of arsenic-mitigation interventions are presented in table 5.39. The capital cost per household is highest for tube wells and pond sand filters. Th maintenance and repair cost is highest for pond sand filter and POU filter. A program to promote interventions is also included with a one-time initial cost. Incremental time use for the interventions is valued at 50 percent of average hourly rural wage rate because more than 85 percent of the population exposed to excessive arsenic in drinking water live in rural areas.

5.6.1.1 Deep tube wells and pond sand filters

The cost of a deep tube well is about Tk 90,000 depending on the actual depth and flow capacity. The cost of a pond sand filter is about Tk 70,000. These cost estimates are based on UNICEF (2011) and Jamil et al. (2019) adjusted for inflation. The interventions are of a capacity to be shared by 10 households. It is assumed that households receiving a deep tube well or pond sand filter need to use five more minutes per day to fetch drinking water compared to their current source of drinking-water supply.

5.6.1.2 Household filtering of drinking water

A household point-of-use (POU) device for filtering drinking water to remove arsenic is relatively inexpensive. The SONO filter developed in Bangladesh costs around Tk 3,400 and can produce as much as 30 liters of filtered water per hour and last at least five years (Akter and Ali 2011). Incremental time use of five minutes per household per day is also included for POU filtering of water. (See table 5.39)

Table 5.39 Cost of arsenic-mitigation interventions

	Deep tube well	Pond sand filter	POU filter
Capital cost (Tk per household)	9,000	7,000	3,400
Useful life (years)	20	20	5
Maintenance and repair (Tk per household year)	250	990	170
Program promotion (Tk per household)	1,000	1,000	1,000
Incremental time use (minutes per household per day)	5	5	5

Source: World Bank.

Table 5.40 presents annualized costs of interventions per household with a discount rate of 5 percent. The largest annualized cost component is incremental time use that is valued at 50 percent of average rural wage rates. Program cost is annualized over the useful life of the intervention and is therefore higher for the POU filter. The total annualized intervention cost per household per year is highest for pond sand filter and lower for POU filter and deep tube well.

Table 5.40 Annualized cost of arsenic-mitigation interventions | ***Tk per household per year***

	Deep tube well	Pond sand filter	POU filter
Annualized capital cost	688	535	748
Annualized program cost	76	76	220
Recurrent maintenance and repair	250	990	170
Incremental time use	1,464	1,464	1,464
Total annualized cost	**2,478**	**3,065**	**2,601**

Source: World Bank estimates.

5.6.2 Benefits of arsenic-mitigation interventions

The health benefits of the arsenic-mitigation interventions are estimated based on the elevated risk of premature mortality from long-term exposure to arsenic in Bangladesh (Argos et al. 2010; Sohel et al. 2009). An estimate of days lived with illness is also included.

Each of the three interventions, if properly implemented, can mitigate nearly all health effects of elevated arsenic exposure. To comply with the WHO guideline of a maximum 10 μg of arsenic per liter of drinking water (10 ppb), 95 percent effectiveness is applied for deep tube wells since some deep tube wells are at risk of arsenic contamination. One-hundred-percent effectiveness is applied for pond sand filters since these filtering systems are designed to remove practically all arsenic. Ninety percent effectiveness is applied for household POU filtering (SONO filter) based on test results reported in Neumann et al. (2013). However, diarrheal-disease incidence; may change—here assumed to increase by 10 percent with substitution from current drinking-water sources (that is, shallow tube wells) to pond sand filters as they can become contaminated during handling and storage. No change in diarrheal incidence is assumed by substitution from shallow to deep tube wells or use of POU filtering device for arsenic removal. Health effects associated with diarrheal disease are estimated using the PIF formula in annex N.

Avoided deaths and illness from the interventions are valued by applying the methodologies in appendixes H and I. This gives benefits per beneficiary household in the range of Tk 92–100 thousand per year (table 5.41).

Table 5.41 Benefits of arsenic-mitigation interventions | ***Tk per household per year***

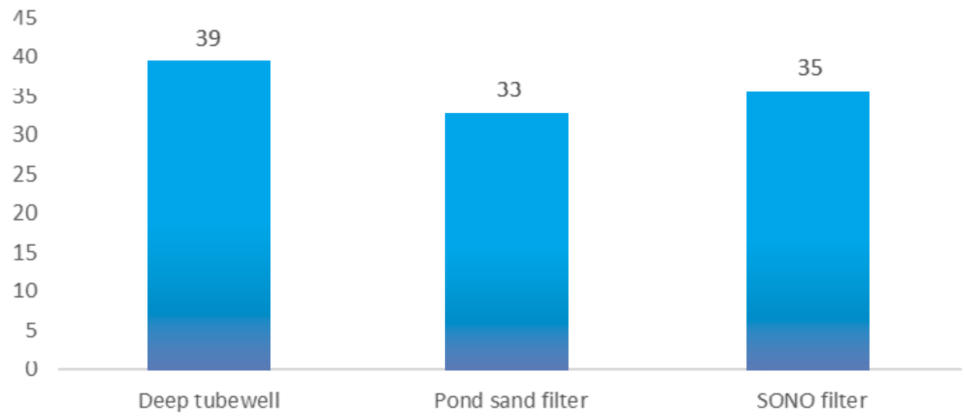
	Deep tube well	Pond sand filter	POU filtering
Arsenic removal	97,048	102,156	91,940
Change in diarrheal disease	0	-2,375	0
Total health benefits	**97,048**	**99,781**	**91,940**

Source: World Bank estimates.

5.6.3 Benefit-cost ratios of arsenic mitigation interventions

The BCRs of the interventions range from 33–39, indicating that benefits are Tk 33–39 for every Tk spent. The BCR is highest for deep tube wells and lowest for pond sand filters (figure 5.9). The BCR for tube wells would be higher where intermediate depth tube wells are arsenic-free because the cost of tube wells increases with depth.

Figure 5.9 Benefit-cost ratios (BCRs) of arsenic-mitigation interventions



Source: World Bank estimates.

The BCRs depend on the arsenic levels in drinking water and range from 23 to 28 for households with 10–50 μg/L arsenic and 38 to 45 for households with more than 50 μg/L arsenic in their drinking water (table 5.42).

Table 5.42 Benefit-cost ratios (BCRs) of arsenic-mitigation interventions

Arsenic (μg/L)	Deep tube well	Pond sand filter	SONO filter
10–50	28	23	25
> 50	45	38	41

Source: World Bank estimates.

5.6.4 Conclusions on arsenic-mitigation interventions

The BCRs of the three interventions for mitigating exposure to arsenic in drinking water are very high—about ten times higher than the BCRs for mitigating the bacteriological pollution associated with inadequate drinking water, sanitation, and hygiene and for mitigating household air pollution. Considering the serious health effects for the population exposed to arsenic and the very high BCRs of interventions, implementation of interventions stands out as a high priority.

5.7 Conclusions

This chapter has presented assessments of costs and benefits of interventions to protect and improve environmental health in Bangladesh. Five environmental health-risk factors have been considered in these assessments. This chapter has examined a wide range of interventions for the control of $PM_{2.5}$ ambient air pollution, addressing household air pollution, mitigating exposure and effects of lead (Pb), avoiding microbiological pollution from inadequate WASH, and avoiding exposure to arsenic in drinking water.

Assessments of other potential environmental health risks such as exposure to arsenic in food and exposure to mercury and cadmium from different sources are not included but are much needed.

The report finds that the BCRs of the assessed interventions reach as high as 134 for $PM_{2.5}$ pollution control, from 1.9 to over 20 for controlling Pb, and from 1.6 to 45 for WASH interventions including addressing arsenic in drinking water. This indicates high rates of return on many investments for protecting health against environmental risks in Bangladesh.

The largest range in BCRs is for ambient $PM_{2.5}$ control interventions. There are interventions that provide extremely high BCRs but with limited ambient $PM_{2.5}$ improvements. There are also interventions that may be achieved at no net cost, or even at net savings. There are also expensive interventions that have a BCR of 0.3 where costs are three times as high as the benefits. Overall, the BCR is as high as 8.8 for a package of comprehensive $PM_{2.5}$ control measures that is estimated to reduce nationwide population-weighted ambient $PM_{2.5}$ by as much as 20 μg/m^3, or one-third of ambient $PM_{2.5}$ concentrations.

The single most-effective intervention to improve ambient $PM_{2.5}$ is reduction or elimination of household use of solid fuel for cooking by having households switch to LPG or electricity; this has the added benefit of reducing the health effects of household air pollution. The intervention is found to contribute to about half of the ambient $PM_{2.5}$ improvement expected from the implementation of a broader comprehensive package of $PM_{2.5}$ control measures. Other interventions with high BCRs include banning agricultural residue burning in the fields, recycling waste that otherwise is burned, and controlling emissions from industry and the power sector. Further control of emissions from cars, buses, trucks, and two-wheelers either provides limited potential for improvement in ambient $PM_{2.5}$ or costs more than the estimated benefits.

The BCRs for four interventions to control household air pollution range from 3.1 to 4.5. The BCRs for the two improved biomass cookstoves are higher than for LPG or conventional electric stoves, but similar or lower than the BCR for electric induction stoves since these stoves have very high energy efficiency. The improved biomass cookstoves provide limited health benefits compared to clean cooking technologies such as LPG and electricity. These interventions are the options for effectively combatting the health effects of solid fuels. In other words, improved biomass cookstoves may be an efficient but not an effective solution for improving the health of the population. Health benefits will be especially large when clean cooking is achieved community-wide.

One priority that emerges from the analysis is to assess further the potential for promoting the use of electric stoves—especially induction stoves—for cooking. This is cheaper than LPG for small electricity users that can benefit from lower electricity tariff rates. With residential block tariffs for electricity pricing, cooking with electricity becomes feasible for less well-off households. Further assessment is also needed regarding the price and non-price obstacles and incentives for adoption of LPG for cooking.

The BCRs of the three interventions to mitigate Pb exposure and impacts range from 1.2 to 21.9. This includes an iron-supplementation intervention for young children with a BCR of 6.6–9.1; hot-spot ULAB site rehabilitation with a BCR of 1.9; and potentially, subject to further studies, an intervention to replace lead-contaminated cookware made from recycled aluminum with a BCR of 1.2–21.9 depending on the magnitude of contamination. Representative BLL measurement studies along with identification of sources of lead exposure are essential to identify further interventions.

The BCRs of interventions for improving household WASH range from 1.6 to 6.0. The interventions with the highest BCRs for addressing microbiological pollution are household point-of-use treatment of drinking water with ceramic filter, safely managed improved non-shared sanitation for households currently having unimproved sanitation, and promotion of handwashing with soap targeting caregivers of children under five. Boiling drinking water using wood or agricultural residues is the least attractive option for improving drinking-water quality, since this practice has negative health effects from generating household air pollution.

The BCRs of the three interventions for mitigating exposure to arsenic in drinking water are very high—in the range of 23 to 45. Considering the serious health effects of arsenic exposure and the very high BCRs of interventions, implementation of interventions stands out as a high priority. The BCRs are highest for deep tube wells. Ponds with sand filters may be an option in locations where deep tube wells are likely to be contaminated with arsenic. A third intervention is household point-of-use (POU) filtering, such as the SONO filter that uses iron and sand filtration, which can effectively remove arsenic in drinking water. However, wide adoption and sustained use of filters have been challenging to achieve. In the short-term, further analysis on water pollution is needed to (a) assess the impacts of and measures to address other highly poisonous heavy metals in both drinking water and rivers, such as lead, mercury, and cadmium, (b) assess the impacts of and potential solutions for freshwater salinization, and (c) identify specific interventions to manage industrial effluent or liquid discharge as well as untreated municipal sewage water.

Implementation of the interventions addressing the five environmental health-risk factors assessed in this report is estimated to prevent over 133,000 deaths per year. This is nearly half of the total annual deaths from the five risk factors. Most of the remaining deaths are due to $PM_{2.5}$ ambient air pollution and lead exposure among adults. A large share of the remaining deaths from ambient $PM_{2.5}$ can only be avoided by Bangladesh cooperating with neighboring countries to address transnational pollution. The main benefit of the interventions to mitigate lead exposure is increased lifetime income from averting IQ losses in early childhood. Interventions must also be identified that mitigate adult lead exposure. For microbiological pollution causing infectious disease and mortality, more advanced interventions would be required to further reduce annual deaths. This includes interventions to improve, for instance, food safety and exposure to polluted surface water. Full implementation of the proposed interventions is expected to avert practically all health effects currently arising from household air pollution caused by the use of solid fuels and from exposure to arsenic in drinking water.

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Endnotes

38 Greenhouse Gas and Air Pollution Interactions and Synergies.

39 "Ambient $PM_{2.5}$" in this section means population-weighted ambient $PM^{2.5}$ unless otherwise stated.

40 Most of the categories contain multiple control measures with a range of emission-reduction potentials and costs per μg/m³ of ambient $PM_{2.5}$ improvement. The measures in each category are ranked from lowest to highest marginal cost per μg/m³. The figure presents the comprehensive control measures for which the benefits exceed the marginal cost of a μg/m³ improvement in ambient $PM_{2.5}$.

41 Costs are net annualized costs—that is, annualized investment costs (5 percent annual discount rate over the expected useful life of the investments) plus annual recurrent costs less any annualized cost savings that the control measures may provide.

42 Because of the nonlinearity or concavity of the IER functions from the GBD 2019.

43 $PM_{2.5}$ control measures in Bangladesh will benefits neighboring countries since air pollution drifts across national borders. These benefits are not included in the estimated health benefits here. For estimates of South Asia regional effects of air pollution, see World Bank (2022).

44 The BCR of LPG for cooking is substantially higher here than in the section on benefits and costs of HAP control. This is because of differences in the treatment of benefits and costs in the BCR. Here, the BCR = health benefits / net cost, with the net cost for LPG being cost net of biomass fuel savings and cooking-time savings in order to be consistent with the GAINS cost-effectiveness analysis. As net cost becomes relatively small, the BCR becomes high. Fuel savings and cooking-time savings are treated as benefits in the section on the benefits and costs of HAP control. Thus, the BCR = (health benefits + fuel savings + cooking-time savings)/cost. This is consistent with the calculation of BCRs for the interventions addressing the two other environmental health-risk factors (that is, microbiological pollution and exposure to arsenic in drinking water). This reduces the BCR.

45 Ambient $PM_{2.5}$ deducted from personal exposure was a rural annual average of 57 μg/m³ for the study by Shahriar et al. (2021) because Shahriar et al included measurements in both the dry and wet seasons. Ambient $PM_{2.5}$ deducted from personal exposure for the study by Berkeley Air Monitoring Group (2022) was 112 μg/m³. This was average ambient $PM_{2.5}$ during the dry season measurement period in the five divisions of the study (mainly January–February 2022).

46 Forty minutes for fuelwood collection and preparation (World Bank 2019) and 20 minutes assumed for agricultural-residue collection.

47 This likely somewhat underestimates the value of biomass fuel used by households since households also purchase some of their fuels at a higher price than reflected in the valuation of collection time.

48 Average household size is 4.3 (BBS/UNICEF 2019).

49 The energy efficiency of an electric induction stove can be as high as 90 percent.

50 Household use of solid fuels not only causes serious air pollution in the immediate household environment, but also contributes to outdoor ambient $PM_{2.5}$ pollution. This is particularly the case if households use TCSs and cook outdoors or vent the smoke out of the dwelling.

51 This likely somewhat underestimates the value of biomass used by households since households also purchase some of their fuels at a higher price than reflected in the valuation of collection time.

52 In calculating the benefit-cost ratios (BCRs) of the interventions, the energy consumption by a TCS is treated as energy saving or benefit when switching to an ICS, LPG, or electric stove and placed in the numerator of the BCR. The energy consumption by an ICS, LPG, or electric stove is treated as cost and placed in the denominator.

53 The promotion-program cost is fixed per targeted household. Therefore, the cost per household that responds to the program increases with lower response rates.

54 EDTA is commonly used for treatment of lead poisoning in children and adults. Benefits and costs of the combination of iron and EDTA are not assessed here, since EDTA is not typically advocated for the general child population.

55 The disability weights are 0.004 for mild, 0.052 for moderate, and 0.149 for severe anemia.

56 https://www.iferi.com/products/6-pcs-stainless-steel-cookware-set-with-lid-kv6608

57 The health damage cost is adjusted by a factor of 0.77 as per appendix N.

58 Tk 3,396 * 2 / 3 = Tk 2,264.

59 The cost of water for households without piped water into their dwelling is calculated as follows: 4.3 minutes collection time per 20 liters of water with time valued at 50 percent of average wage rate. The calculation of the collection time is based on 77 percent of households having water on premises outside their dwelling (three minutes collection time), and 18 percent having water outside their premises (10 minutes collection time). The household water location is from (BBS/UNICEF 2019).

CHAPTER 6. AIR QUALITY MANAGEMENT IN THE GREATER DHAKA AREA

6.1 Introduction

Managing a city's air quality can involve several different goals, from reducing concentration of pollutant gases to reducing fine and coarse particulate matter; from reducing premature mortality numbers by reducing the annual average pollution levels that people are exposed to, to temporarily restricting polluting activities to bring down pollution levels during peak times. It could also focus on improving indoor air quality.

This chapter presents an initial air quality management (AQM) strategy for the Greater Dhaka Area (GDA), that focuses on reducing the population weighted annual average concentration of outdoor fine particulate matter (PM). The GDA, for the purposes of this initial strategy, comprises five of the Dhaka Division's thirteen districts: Dhaka, Narayanganj, Gazipur, Narsingdi, and Munshiganj (figure 6.1). The reasons for focusing on the GDA are:

- Bangladesh's highest air pollution concentrations are in the GDA; therefore, the potential for the most substantive improvement in air quality and thereby in human health conditions can be developed and implemented in the GDA.
- The GDA includes about 28 million people, or as much as 17 percent of Bangladesh's population.
- The most detailed air quality, source apportionment, and sector data are available for the GDA; therefore, the most precise AQM strategies and action plans can be developed.

The chapter explores how the average GDA resident's exposure to ambient $PM_{2.5}$, the most harmful air pollutant for human health, could be brought down to the WHO's annual Interim Target 1 of 35 μg/m³. It addresses the current understanding of the GDA's air quality situation and quantifies the sources of ambient $PM_{2.5}$ concentrations in the five GDA districts in 2019–20. It assesses how the contributions from the sources in the GDA will likely develop up to 2030. This assessment is based on projections of socioeconomic activities and assuming full implementation of already decided policies and measures to control air pollution. The chapter examines the scope of $PM_{2.5}$ exposure reductions that could be achieved by measures that can be taken within the GDA and analyzes their cost-effectiveness. Subsequently, the chapter discusses the interplay between measures taken within the GDA and the inflow of pollution to the GDA from other areas within the Indo-Gangetic Plain (IGP) airshed and the role of that interplay in cost-effectively achieving ambient air quality targets.

Figure 6.1 (1) Bangladesh, (2) Dhaka Division, and (3) Greater Dhaka Area (GDA)

Sources: (1) https://www.mediabangladesh.net/map-of-bangladesh/ (2) https://store.mapsofworld.com/digital-maps/country-maps-1-2-3/bangladesh/dhaka-divisions (3) GDA map (w/ AAQM stations) developed by World Bank.

This chapter's modeling results and its suggested strategies and policies for improving air quality in the GDA can help Bangladesh strengthen its green growth strategy, as envisaged in the Bangladesh Perspective Plan 2021–2041 and in the current 8th Five-Year Plan (2021-25) (8FYP). Implementing the clean air programs to reach the air quality improvement targets suggested in this chapter will (a) generate substantive climate co-benefits relating to carbon dioxide (CO_2) emissions and short-lived climate pollutants like black carbon (BC) and methane (CH_4), (b) generate substantive new jobs in cleaner production, and (c) stimulate economic development in the lowest-income areas (World Bank 2022).

6.2 Air quality in Bangladesh

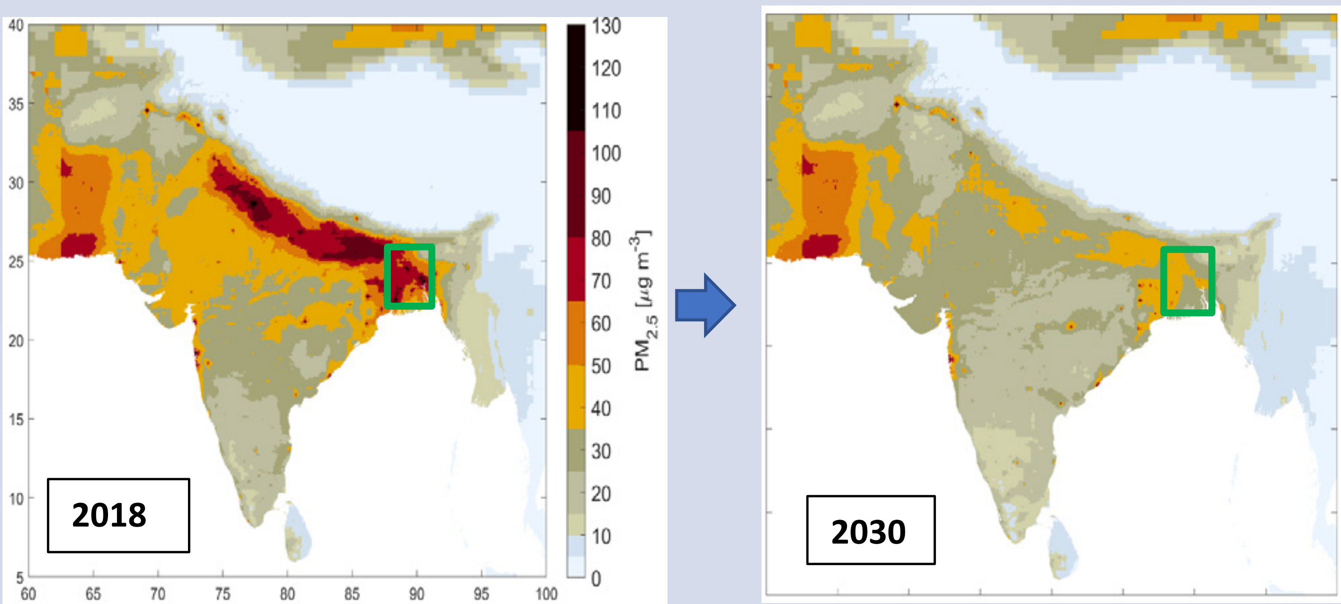
Bangladesh's air quality is among the world's worst. Among cities in IGP countries (Bangladesh, India, Nepal, and Pakistan), ambient $PM_{2.5}$ concentrations in Dhaka city ranks second, surpassed only by Delhi. The average ambient $PM_{2.5}$ concentration in Bangladesh in 2022 was about 64 μg/m³. In Dhaka, the concentration was as high as 90 to 100 μg/m³. This is approximately 2.7 times Bangladesh's ambient air quality standard of 35 μg/m³ and approximately 20 times the World Health Organization's (WHO) air quality guideline (AQG) value of 5 μg/m³ for annual average concentrations of $PM_{2.5}$. Combining ambient air pollution (AAP) and household air pollution (HAP), air pollution is currently the third-highest health risk factor in Bangladesh. That situation is projected to stay as such to 2030 in the current "business-as-usual" (BAU) scenario for air pollution, given the very limited expected improvements in air quality that current policies offer.

An important factor for the high $PM_{2.5}$ concentrations in Bangladesh—and Dhaka in particular—is their location within the eastern part of the IGP, where Bangladesh, West Bengal, and parts of Jharkhand and Bihar form a natural airshed. This airshed is based on typography (surrounded by hills and mountains), meteorology (a prevailing west-to-east wind, particularly during dry season), and economic conditions (a largely diversified economy within the airshed that creates several pollution sources). Because of transboundary effects of air pollution, getting better air quality requires collective action. More importantly, by cooperating with other IGP countries, Bangladesh could benefit from faster and lower cost results in improving air quality. Based on a dialogue where the World Bank has supported the countries in the South Asia Region (SAR) to enhance AQM cooperation—particularly among the IGP countries—a Clean Air 2030 Vision has been developed (box 6.1).

Box 6.1 SAR Clean Air 2030 Vision

The SAR Clean Air 2030 Vision was developed in early 2021, recognizing that air pollution does not respect political boundaries and that regional coordination of analytics and harmonization of policies will benefit all IGP countries to achieve clean air goals faster and cheaper than individual action. The goal of this vision is to achieve the WHO Interim Target 1 for annual ambient $PM_{2.5}$ of 35 μg/m³ or better for the IGP countries by the beginning of the next decade. For SAR and Bangladesh, this would imply the improvements in air quality depicted in figure B6.1.1. By achieving the Clean Air 2030 Vision, most of Bangladesh would experience $PM_{2.5}$ concentrations between 20 and 35 μg/m³.

Figure B6.1.1 SAR Clean Air 2030 Vision



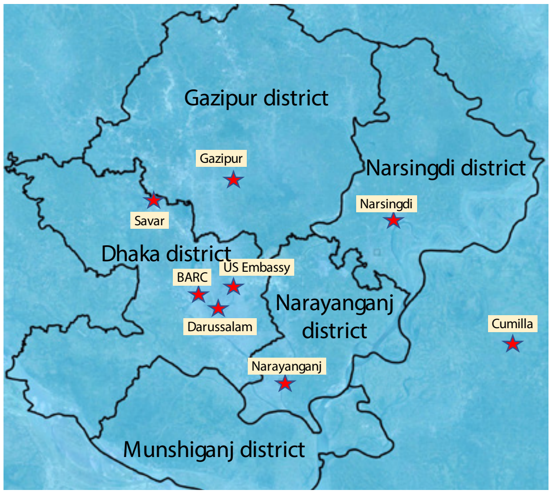
Source: World Bank 2022a.

Source: World Bank. 2022a.

6.2.1 Spatial trends in ambient $PM_{2.5}$ in the Greater Dhaka Area

Considering the higher population density in the GDA compared to other parts of the country, the population-weighted $PM_{2.5}$ exposures are expected to be substantially higher in the GDA than elsewhere in Bangladesh. For the available four sites within Dhaka district, the measured annual ambient $PM_{2.5}$ concentrations are in the range of 83 to 98 μg/m³, indicating relatively low spatial variation within the district. Sites located near Dhaka district, such as Gazipur and Narayanganj, also exhibit similar concentrations. These areas are growing cities with land-use patterns comparable to those of Dhaka city. However, a site located approximately 100 kilometers away from Dhaka city, Cumilla (see figure 6.2), demonstrates lower concentrations compared to sites within the GDA.

Figure 6.2 GDA monitoring stations and their annual ambient $PM_{2.5}$ concentrations, 2019–20



District	Station	$PM_{2.5}$ (μg/m³)
Dhaka	Darussalam	98
	BARC	93
	US Embassy	83
	Savar	89
Narayanganj	Narajanganj	97
Gazipur	Gazipur	81
Narsingdi	Narsingdi	67
Munshiganj	None	–
	Cumilla	55

Source: World Bank based on sources from DoE.
Note: – = Not available.

6.2.2 Air quality landscape: Long-term spatiotemporal trends in $PM_{2.5}$ in Bangladesh

Long-term trends in ambient $PM_{2.5}$ are analyzed here from 2012 to 2022. Ten stations in Bangladesh have monitoring data for this period of which four are in the GDA. The sites in the GDA exhibit relatively higher concentrations, while the eastern sites of Sylhet and Chittagong have lower concentrations. Moreover, the western part of the country experiences higher concentrations.

These regional differences in concentration levels can be attributed to variations in local source strength and the impact of transboundary pollution. The western sites, in particular, may be more influenced by the inflow of transboundary pollution from India and other parts of the IGP region, given the prevailing wind direction during the dry season (World Bank 2022a). Conversely, during the wet season, the prevailing winds from the Bay of Bengal contribute to transported-pollution levels that are relatively lower.

Table 6.1 summarizes the rate of change in ground-level $PM_{2.5}$ at the four monitoring sites in the GDA from 2012 to 2022. These sites experienced higher rates of increase than other sites nationwide. Outside of the GDA, the sites in Rajshahi, Khulna, and Barisal also showed an increase in ground-level $PM_{2.5}$. The site in Sylhet displayed a decline of 1.5 μg/m³ per year, while the two sites in Chittagong showed no statistically significant change.

Table 6.1 Rate of increase in annual mean $PM_{2.5}$ in GDA, 2012–22

Location	Increase per year (μg/m³)	% increase per year
Dhaka (BARC)	2.1	2.0
Dhaka (Darussalam)	2.3	2.2
Narayanganj	2.0	2.0
Gazipur	2.4	2.1

Source: World Bank based on monitoring data from the Department of Environment (DoE).

6.3 Sources of $PM_{2.5}$ Exposure in the Greater Dhaka Area in 2020

6.3.1 Methodology

This section presents an initial comprehensive emission inventory of primary $PM_{2.5}$ emissions and $PM_{2.5}$ precursors and quantifies the contributions of the various emission sources to ambient $PM_{2.5}$ in the GDA in 2019–20. This source apportionment was conducted with the GAINS City model tailored to the GDA. The model is a state-of-the-art scientific model of cost-effectiveness of air quality measures. It is applied to the GDA's meteorological conditions and fed with an inventory of emissions of all $PM_{2.5}$ precursor substances in the entire IGP airshed. Computed ambient $PM_{2.5}$ is compared against available monitoring data, and the resulting population exposure in the GDA is estimated using fine-scale population data.

The GAINS-City model is a new version of the widely applied GAINS model (Amann et al. 2011) that is tailored to the challenges of specific cities. The GAINS model provides the scientific backbone for the development of cost-effective regional AQM strategies in Europe under the Convention on Long-range Transboundary Air Pollution (CLRTAP) and in the European Union with its member states (Reis et al. 2012). Adapted to other world regions, the GAINS model is now also used to inform governments in China, India, and other countries about cost-effective AQM (for example, World Bank 2022a).

The new GAINS-City model has evolved to support the development of investment strategies for specific urban agglomerations (World Bank 2021). Relying on the full scientific basis and the regional databases of the GAINS model, GAINS-City tailors its analyses to a given city, greatly reducing the demand for data and the complexity of analyses. At the same time, it improves the description of local conditions, with a focus on the sources most relevant for pollution exposure and greenhouse gas (GHG) emissions in the city.

This section presents an initial comprehensive emission inventory of $PM_{2.5}$ precursors for the GDA. The inventory is based primarily on local information collected for this study. Data gaps have been filled with information from other IGP regions compiled in previous work for the GAINS-IGP model (IIT Delhi and IIASA 2023) and adjusted to the GDA's local situation. Emissions of primary $PM_{2.5}$ as well as the precursors of secondary $PM_{2.5}$—that is, SO_2, NO_x, and ammonia (NH_3)—are estimated for the five GDA districts with a 1 km x 1 km spatial resolution, consistent with the complete inventory for the entire IGP airshed that has been developed for the GAINS-IGP model. This airshed approach enables a full cost-effectiveness analysis of a large range of emission-control measures.

The model also estimates (a) emission-control costs of about 1,100 possible emission-control options in the GDA, (b) their impact on ambient $PM_{2.5}$ concentrations and population exposure in the GDA, and (c) the cost-effectiveness of each emission-control measure for reducing $PM_{2.5}$ exposure in the region. A ranking of the possible control options according to their marginal costs identifies portfolios of the most cost-effective control measures for achieving given targets for reducing $PM_{2.5}$ exposure. Together with an understanding of the likely future inflow of pollution from other regions in the eastern IGP airshed, these data provide important information for setting realistic targets on air quality in the GDA and information on how these targets might be achieved in cost-effective ways.

6.3.2 GAINS-City for the Greater Dhaka Area

The calculation of ambient $PM_{2.5}$ considers the contributions of (a) primary $PM_{2.5}$ emissions (soot, fly ash, road dust, and so on); (b) secondary particles, which are formed through chemical reactions from gaseous precursor emissions of SO_2, NO_x, NH_3, and volatile organic compounds (VOCs); and (c) windblown soil dust. For each of these pollutants, the analysis identifies the sectoral origin and locations where they are emitted. Emissions of VOCs are considered in the source apportionment, although their sources are not addressed here in detail.

Emissions of these substances in each of the five districts are computed, for each of the 400 source categories considered in GAINS, as a product of the amount of emission-generating activity (for example, fuel consumption) and an emission factor representative of local conditions, considering the efficiency of applied emission controls.

The analysis for the GDA draws primarily on local information collected for this study. The analysis compiled activity data on household energy use, power plants, transportation, brick kilns, small industries, agriculture, and waste from multiple local sources. Household energy use data are derived from the Multiple Indicator Cluster Survey 2019 conducted by the Bangladesh Bureau of Statistics (BBS 2019), providing information about cooking practices and fuel categories. The power-plant database is obtained from the Bangladesh Power Development Board, while yearly vehicle-registration information is sourced from the Bangladesh

Road Transport Authority. District statistics from the Bangladesh Bureau of Statistics offer data on agricultural activities and the number of restaurants and small and medium industries, while waste data are obtained from the Bangladesh Waste Database 2014 compiled by Waste Concern. Specific industry information, such as brick kilns, steel factories, and cement factories, is gathered from an inventory by the Department of Environment (DoE).

Local data on emission factors were not available for all source categories used in the GAINS modeling framework. Data gaps have been filled with information from other countries in the IGP that has been compiled in previous work for the GAINS-IGP model (IIT Delhi and IIASA 2023) and adjusted to the local situation.

The local dispersion of primary $PM_{2.5}$ emitted from sources within the GDA was computed with the Iowa Urban Dispersion model specially developed for this study. The resulting ambient $PM_{2.5}$ concentrations are then superimposed on concentrations of primary and secondary $PM_{2.5}$ from sources outside the GDA computed with the GAINS model. Anthropogenic precursor emissions of NM-VOC have not been further explored in this initial analysis since the analysis suggests that they have only a small impact on $PM_{2.5}$ concentrations.

Ambient $PM_{2.5}$ concentrations are aggregated to annual mean, which is the most relevant metric associated with health impacts. $PM_{2.5}$ population exposure is then calculated by multiplying $PM_{2.5}$ concentrations computed with a 1 km x 1 km resolution for the whole GDA domain with respective population distribution.

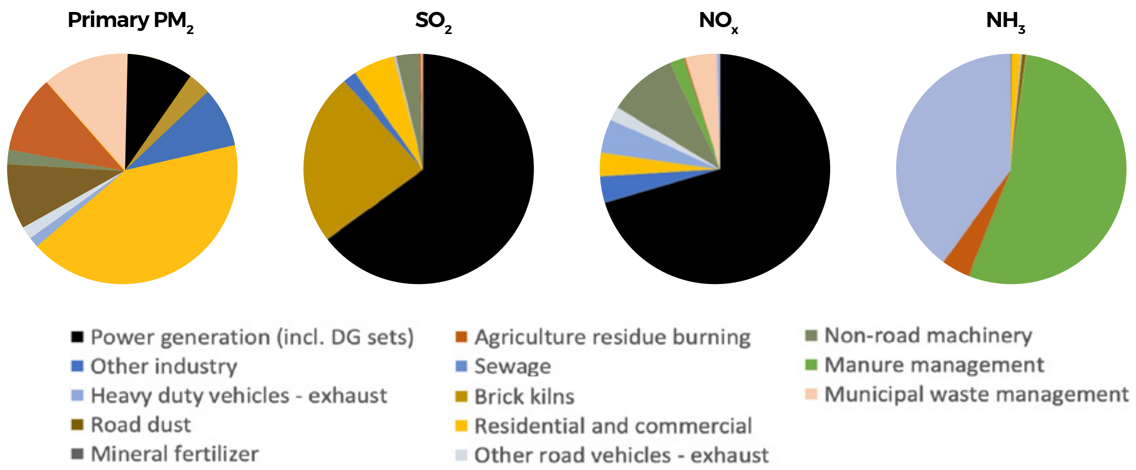
6.3.3 Emissions of $PM_{2.5}$ precursors

Many of the underlying statistics for estimation of emissions were available only up to 2020 at the time of preparing this report. Since the COVID-19 lockdowns in 2020 made that year exceptional, the analysis focused on the two-year period 2019–20.

Estimated primary $PM_{2.5}$ and NH_3 emissions were highest in the Dhaka district owing to the largest population, while SO_2 and NO_x emissions were highest in Gazipur and Narayanganj mainly due to its high density of industrial sources. However, emissions per capita were lowest in the Dhaka district, highest in Narajanganj for SO_2 and NO_x, and highest in Narsingdi for NH_3 reflecting the significant differences in the economic structures across the districts.

More than 40 percent of all primary $PM_{2.5}$ emissions in the GDA originated from the residential sector, mainly from solid fuel used for cooking, municipal waste management, road dust, power generation, and industrial activities contributed about 10 percent each (figure 6.3).

Figure 6.3 Sector contributions to emissions of $PM_{2.5}$, SO_2, NO_x, and NH_3 in the GDA, 2019–20



Source: World Bank calculations.

The available data suggest sources that received high public attention in the past, such as road vehicle exhaust and brick kilns, are not the largest contributors to emissions. Over the entire GDA, road vehicles constitute a smaller share of primary $PM_{2.5}$ emissions than in many other countries due to the much lower car ownership in Bangladesh. Obviously, compared to total emissions in the GDA, road vehicles contribute a larger share to $PM_{2.5}$ concentrations in ambient air near busy roads in Dhaka city center where poor air quality is prominently perceived by the public. For brick kilns, the analysis employs a recent brick-kilns database from the DoE, which includes the specific location of individual brick kilns, annual production, kiln technology, and fuel type. Characteristic emission factors by kiln technology and fuel are drawn from the available research and related literature. In addition, the seasonal pattern of brick production is considered here.

The picture looks fundamentally different for the precursor emissions of secondary $PM_{2.5}$. Power plants account for about two-thirds of total SO_2 and 70 percent of NO_x emissions, which are important precursors of secondary $PM_{2.5}$ in the atmosphere. Brick kilns contributed 25 percent of total SO_2 but only 3 percent of primary $PM_{2.5}$ emissions. These estimates consider the typical brick-kiln technologies prevalent in the GDA in 2020 and the use of emission factors that have been measured for these technologies in other South Asian countries. Mobile sources (including non-road mobile machinery) account for only 15 percent of all NO_x emissions. SO_2, and to a lesser extent NO_x, react in the atmosphere with NH_3 to form ammonium sulphate and ammonium nitrate particles. An estimated 50 percent of total NH_3 emissions in the GDA are caused by the application of mineral fertilizer and about 40 percent by the wastewater sewerage system. For non-road mobile machinery (construction, agriculture, and ships), a 9 percent contribution is estimated for NO_x emissions and 2 percent for $PM_{2.5}$ and SO_2 emissions, respectively. Note that these numbers relate to the total GDA area; local situations at hot spots (for example, busy streets) will be higher.

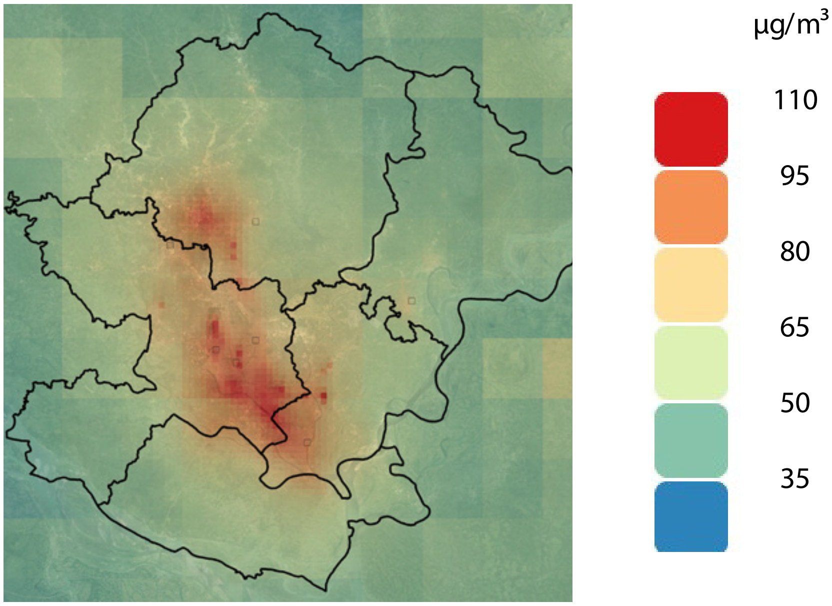
As might be expected, higher road and traffic densities in Dhaka city center cause higher emissions from road transport than in other areas. Households make large contributions to primary $PM_{2.5}$ emissions throughout the GDA, even in Dhaka district where most of the wealthy households in the center have switched to clean fuels for cooking. However, there is still a considerable amount of solid-fuel use reported for the households in Dhaka district.

6.3.4 Ambient $PM_{2.5}$ concentrations

The GAINS-City model has been used to estimate annual mean concentrations of $PM_{2.5}$ in ambient air in the GDA. The calculation considers the spatial and temporal distributions of the various emission sources, their release heights, meteorological conditions of 2020, the chemical processes that produce secondary $PM_{2.5}$, the inflow of $PM_{2.5}$ from outside sources, and the background load from windblown soil dust.

Annual ambient $PM_{2.5}$ concentrations reach more than 100 μg/m³ in the Dhaka city center as well as in the vicinity of some power stations outside the city. The levels in rural areas are generally lower; however, throughout the whole region, concentrations exceed the Bangladesh's own $PM_{2.5}$ standard and WHO $PM_{2.5}$ Interim Target 1 (WHO 2021) both of 35 μg/m³ (figure 6.4).

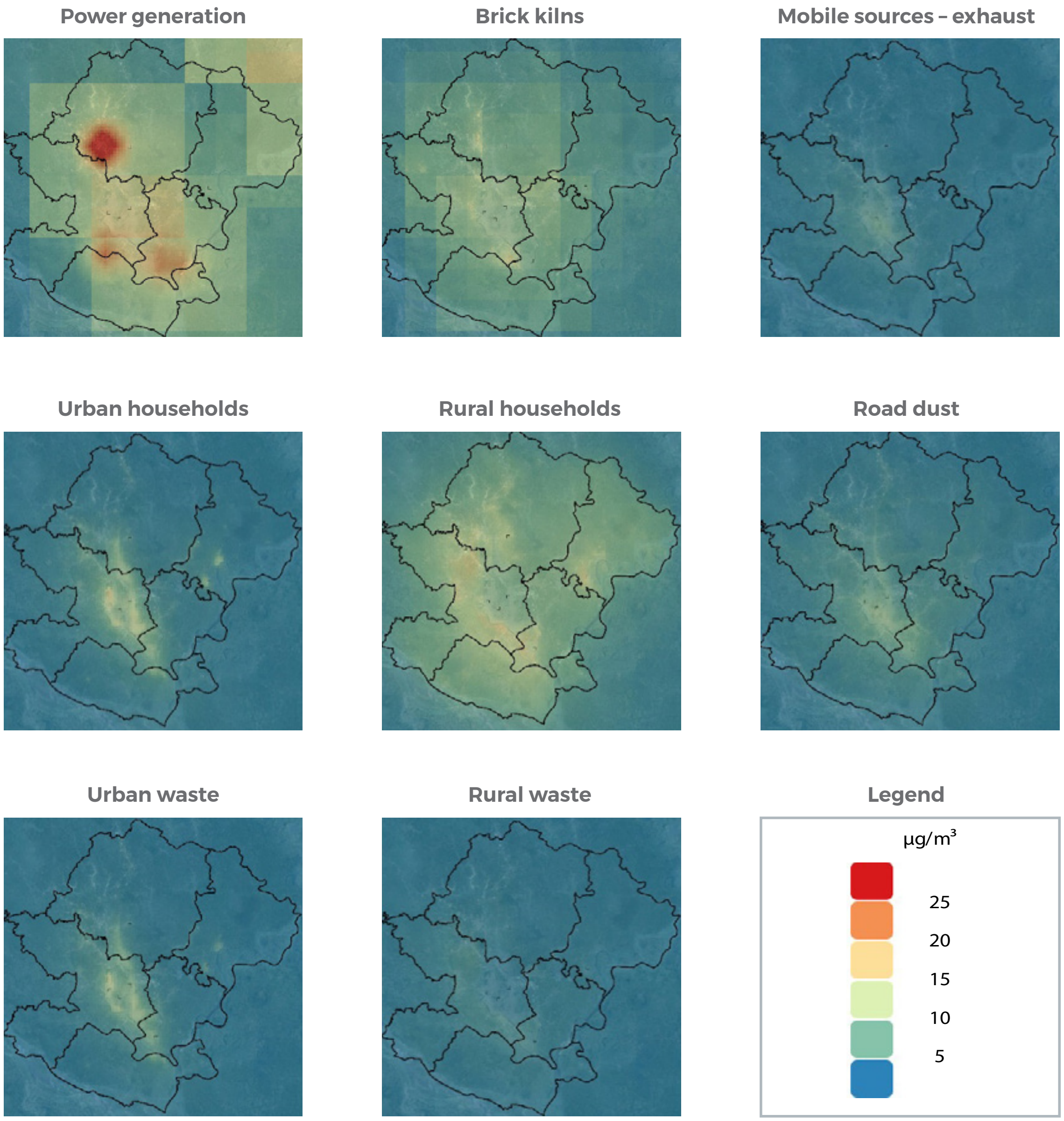
Figure 6.4 Computed mean annual ambient $PM_{2.5}$ in GDA, 2019–20



Source: World Bank calculations.

The geophysical approach of the atmospheric dispersion model employed by GAINS-City makes it possible to track the fate of emissions emerging from specific sources and to thereby quantify their contributions to total ambient $PM_{2.5}$ concentrations throughout the GDA. Figure 6.5 displays the contributions from key emission-source categories computed for 2019–20. Over the whole area, power-generation sources that disperse their emissions through high stacks—especially plants located outside the Dhaka city center—make the largest contribution to $PM_{2.5}$ concentrations, followed by brick kilns and rural households using solid fuels. The impacts of other sources are felt more locally where they can lead to high concentrations.

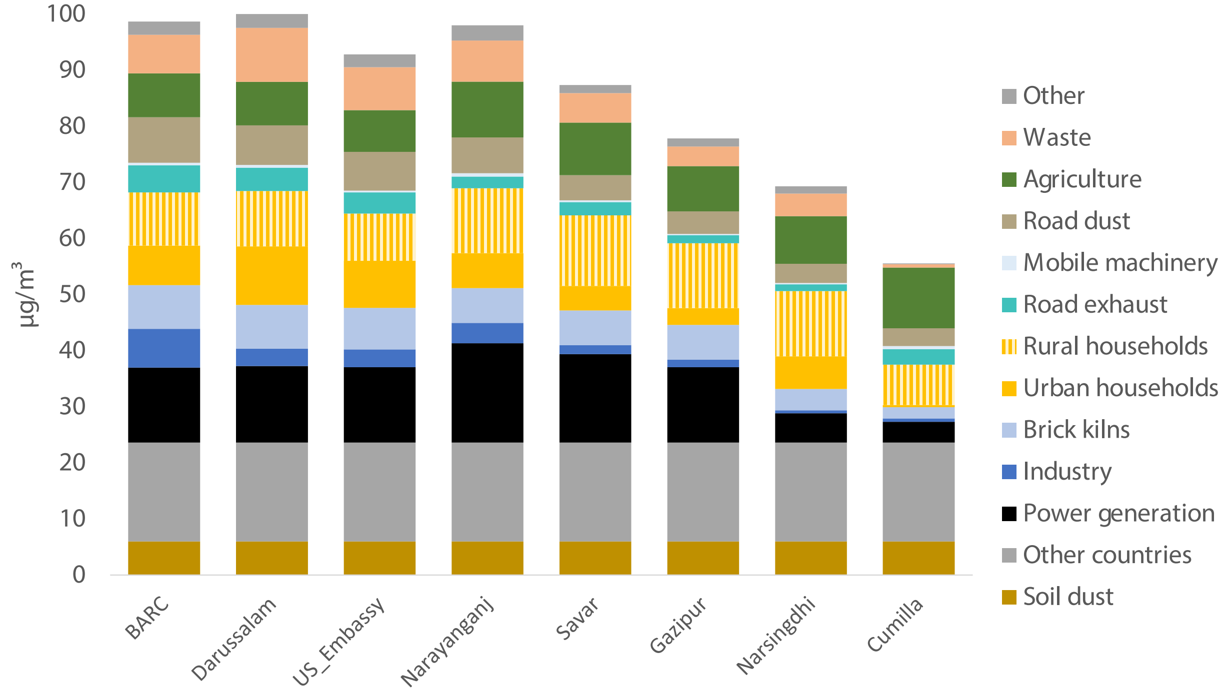
Figure 6.5 Annual ambient $PM_{2.5}$ concentrations originating from key emission sectors in the GDA, 2019–20 | *μg/m³*



Source: World Bank calculations.

An analysis of the relative contributions at individual locations (for example, for specific monitoring sites) provides important information for establishing compliance with air quality standards, since that analysis reveals the importance of the various emission sources for the different monitoring sites. As shown in figure 6.6, there are variations in the relative shares of the source categories across the GDA, depending on the locations of the monitoring sites and emission sources.

Figure 6.6 Source apportionment of annual mean $PM_{2.5}$ concentrations for the monitoring sites, 2019-20



Source: World Bank calculations.

In contrast to widely used air quality metrics that refer to the worst conditions, aggregated metrics are more informative to address the burden of air pollution on public health and to maximize the health benefits from pollution-control interventions. For this purpose, mean population exposure to annual $PM_{2.5}$ has been found as a relevant metric. This report focuses on population exposure within the five GDA districts, considering the inflow of pollution from outside areas as well as the transport of pollution across the five districts.

Due to the large spatial differences of population densities within each district, population-weighted exposure might be higher or lower than concentrations observed at fixed monitoring sites, depending on the station's location (table 6.2).

Table 6.2 Modelled ambient $PM_{2.5}$ population exposure in GDA, 2019-20

District	Population-weighted ambient $PM_{2.5}$ (µg/m³)
Dhaka	92
Narayanganj	88
Gazipur	73
Narsingdi	63
Munshiganj	72
GDA (all five districts)	84

Source: World Bank calculations.

Cost-effective air quality management aimed at public health needs to tailor emission controls such that population exposure to $PM_{2.5}$ will be reduced at least cost. The selection of cost-effective emission controls is informed by source apportionments for population exposure in the target region. Figure 6.7 provides such source apportionments for the five GDA districts. The graphs indicate the contributions to $PM_{2.5}$ exposure that originate from (a) natural emission sources—that is, soil dust; (b) other countries; (c) districts in Bangladesh outside the GDA regions; (d) surrounding GDA districts; and (e) the district itself. Contributions are broken down by the source sector.

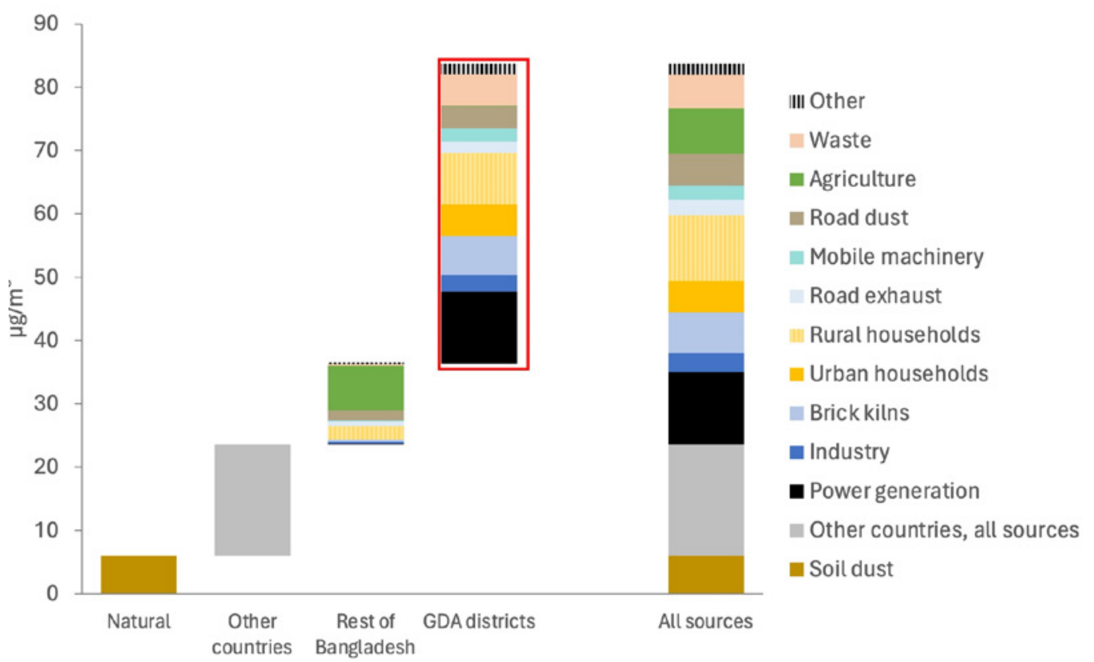
For Dhaka district, average population exposure is slightly lower than concentrations at the stations in the city center but higher than for all the GDA. Out of the total annual exposure of 92 μg/m^3, about one-third originates from sources outside the GDA—that is, from other regions in Bangladesh, other countries, and from natural sources. About two-thirds are caused by emissions within the GDA, out of which about half is transported into the Dhaka district from emission sources in the other four GDA districts. The largest local sources of $PM_{2.5}$ exposure include households (mainly solid-fuel cookstoves) and waste management. The inflow from other GDA districts is dominated by power-generation plants followed by household cookstoves and brick kilns. In contrast, agricultural sources (e.g. fertilizer application) cause the main inflow from sources that are outside the GDA but within Bangladesh.

Annual population exposure in the four other GDA districts (~72 μg/m^3) is lower than in Dhaka district. As in Dhaka district, local emissions contribute only a minor share (between 13 and 30 percent) to total exposure; the rest is imported from outside regions. Between 50 and 60 percent of total exposure originates from the GDA districts, and 20–37 percent from other regions in Bangladesh. Between 15 and 20 percent is linked to sources in other countries.

Focusing on the GDA, 56 percent of population-weighted annual mean $PM_{2.5}$ exposure of 84 μg/m^3 is linked to emission sources within the GDA (figure 6.7). The largest share (28 percent) of this local contribution originates from households, mainly biomass cookstoves, followed by power plants in the GDA (24 percent). Thirteen percent emerges from brick kilns in the GDA and 11 percent from the open burning of municipal solid waste. Road dust accounts for about 8 percent, and exhaust emissions from road transport for 4 percent (mainly diesel heavy-duty vehicles).

Around 65 percent of the population-weighted annual mean $PM_{2.5}$ concentration in the GDA (84 μg/m^3) is primary $PM_{2.5}$ (PPM) and 35 percent is secondary $PM_{2.5}$ (SPM). About half of SPM in the GDA is formed through chemical reactions from sources within the GDA—mainly from power plants (SO_2 and NO_x emissions) and some from brick kilns (SO_2 emissions), while nearly one-third is from outside Bangladesh (mainly India) and the rest is from the rest of Bangladesh (mainly NH_3 from agriculture). To control the generation of SPM, an equal effort must be done in neighboring countries and the rest of Bangladesh besides inside the GDA itself.

Figure 6.7 Source apportionment of annual $PM_{2.5}$ population exposure in the GDA in 2020



Source: World Bank calculations.

The source apportionment analysis clearly demonstrates that effective air quality management strategies require cooperation across multiple jurisdictions. Even moderate air quality improvements in individual GDA districts must involve sources in the entire GDA. For approaching air quality targets such as the WHO Interim Target 1 (the same as Bangladesh's new air quality standard for annual $PM_{2.5}$), coordination across the IGP airshed will be indispensable.

6.4 Cost-effective emission controls in the Greater Dhaka Area

This section presents a cost-effectiveness analysis that ranks available emission-control measures by pollution-control costs that occur for the entire economy over the full lifetime of pollution-control equipment. The section explores how ambient $PM_{2.5}$ concentrations could be brought down to the WHO's annual Interim Target 1 and Bangladesh's own $PM_{2.5}$ standard of 35 µg/m^3 by 2030. The section examines the scope for $PM_{2.5}$ exposure reductions that could be achieved by measures taken inside the GDA and analyzes the cost-effectiveness of the individual measures. The section subsequently examines the air quality improvement that can be achieved in the GDA by emission control measures taken elsewhere in Bangladesh and in the larger IGP airshed that affects air quality in the GDA.

The analysis of cost-effective emission-control measures for air quality improvements in this section is carried out with the GAINS model that has been tailored to the IGP. The model estimates emission-control costs in the GDA from possible control options, their impact on ambient $PM_{2.5}$ exposure in the GDA, and the cost-effectiveness of each measure for reducing $PM_{2.5}$ exposure in the region. A ranking of the possible options according to their marginal costs identifies portfolios of the most cost-effective measures for achieving ambient $PM_{2.5}$ exposure reduction targets. Together with an understanding of the inflow of pollution from other regions in the eastern IGP airshed, these data provide important information for setting realistic targets on air quality in the GDA and information on how these might be achieved in cost-effective ways.

6.4.1 Baseline ambient $PM_{2.5}$ projections in the GDA

A baseline projection of ambient $PM_{2.5}$ in the GDA for 2030 is first developed in this section that illustrates the likely consequences of population and economic growth and progressive implementation of current emission-control legislation on air quality. The population in the GDA is assumed to increase by about one percent per year from 2020 to 2030. Along with the vision to become a high-income nation by the year 2041, GDP per capita is assumed to grow by 5.3 percent annually, so that total economic output in 2030 will be 80 percent higher than in 2020 considering population growth. Targeted economic policies will direct most of the additional activities to less energy-intensive sectors, while production volumes of brick kilns and steel rerolling will stabilize. This socioeconomic trend together with enhanced energy-efficiency policies will limit the increase in total primary energy consumption to less than 25 percent from 2020 to 2030. The demand for private mobility will more than double from 2020 to 2030 at an annual rate of 8.3 percent per year, and the freight transport volume will increase by about 150 percent.

The baseline projection also reflects the effect on ambient $PM_{2.5}$ of pollution-control measures that were already implemented in 2020 or for which implementation is expected by 2030 because of recent legislation (Table 6.3).

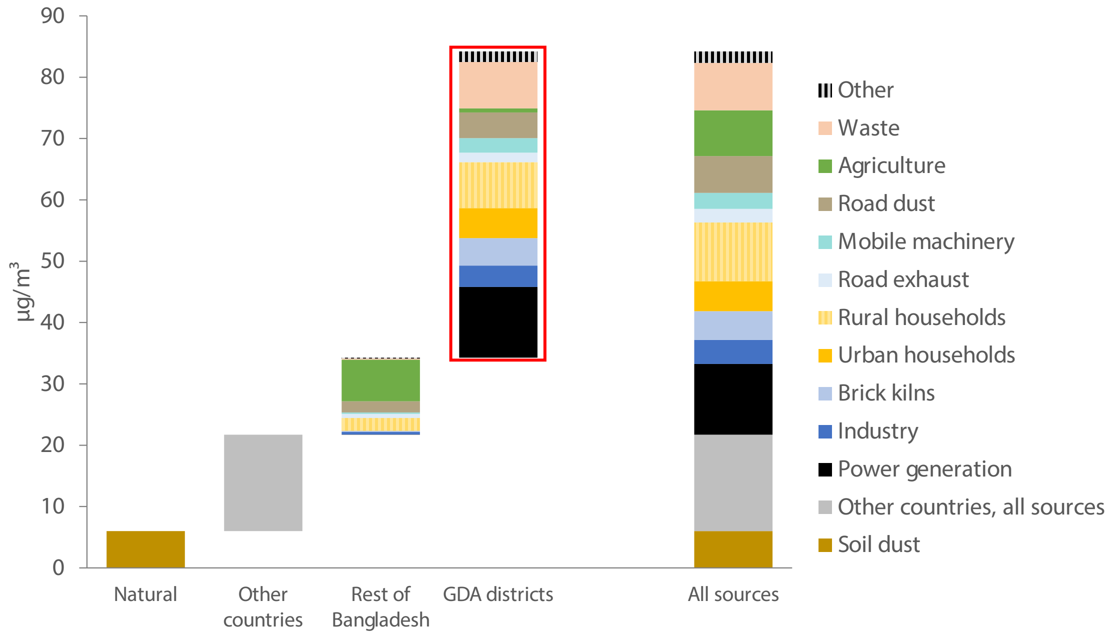
Table 6.3 Measures assumed in the baseline ambient $PM_{2.5}$ for 2030

Mobile sources:
• Heavy-duty trucks and buses, diesel: In 2030, 50% of fleet with Euro IV, older vehicles Euro I
• Light-duty vehicles (cars and vans), gasoline, diesel, LGP: In 2030, 50% of fleet with Euro 4, older vehicles Euro 1 • Light-duty vehicles (cars and vans), CNG: Stage 3 controls
• Two-wheelers, gasoline: Stage 1 controls
• Two-wheelers, CNG and LPG: Stage 3 controls
Households:
• Partial collection and centralized disposal of municipal waste in urban areas
Industry:
• Basic PM controls (cyclones/ESP1) in most industrial sectors (90% of fuel consumption)
• Moderate PM controls (ESP2) in a few industrial sectors (cement, fertilizer) • Brick kilns: By 2030, 15% of total capacity will be modern kilns (zig-zag, Hofman, VSBK, tunnel kilns); the rest will be fixed-chimney bull's trench kilns

Source: World Bank analysis.

The socioeconomic assumptions listed above, and especially the adopted emission controls in table 6.3, imply a clear decoupling of economic growth and $PM_{2.5}$ precursor emissions, with only slight increases of $PM_{2.5}$ precursor emissions from 2020 to 2030. This leads to only minor changes in population-weighted exposure to $PM_{2.5}$ in the GDA with average exposure estimated to remain high at 84 μg/m³ in 2030. The source contribution to population-weighted ambient $PM_{2.5}$ in 2030 is very similar to the situation in 2020. Nearly 35 μg/m³ of ambient $PM_{2.5}$ is from emissions originating in the rest of Bangladesh, in other countries, and from natural sources (dust), while sources in the GDA contribute about 50 μg/m³ as depicted by the red rectangle in figure 6.8. This red rectangle refers to the sources that can be influenced by interventions within the GDA.

Figure 6.8 Baseline source apportionment of ambient $PM_{2.5}$ population exposure in the GDA in 2030



Source: World Bank calculations.

The baseline ambient $PM_{2.5}$ projection illustrates the consequences on ambient $PM_{2.5}$ in the GDA of BAU from 2020 to 2030 with no additional emission control measures implemented than those presented in table 6.3. However, a wide range of policy measures is conceivable that could improve air quality. Considering the emission-control measures that are included in the GAINS model, the cost-effectiveness of technical control options that could reduce emissions and thereby lower ambient $PM_{2.5}$ exposure in the GDA have been examined in this study with the GAINS-City model. This analysis does not address the potential from changes in human behavior that would affect the demand for energy services—changes such as turning up thermostats to reduce the demand for air conditioning or switching from cars to bicycles to reduce motorized mobility.

6.4.2 Cost-effective emission control measures

The potential population-weighted ambient $PM_{2.5}$ exposure reductions in the GDA and costs of the emission control measures from the GAINS-City model that may be implemented in the GDA are presented in table 6.4. About 90 measures emerge as potentially cost-effective means for reducing $PM_{2.5}$ exposure at different costs and with different reduction potentials. These measures are clustered into 13 groups that deliver exposure reductions in the GDA by nearly 40 μg/m³ from 84 to 45 μg/m³ in 2030. The marginal cost of the measures ranges from net cost savings, or negative marginal cost of $28 million, to as high as $125 million per year per μg/m³ improvement in population-weighted ambient $PM_{2.5}$. The total cost of implementing the measures is estimated at $285 million per year.

The marginal costs of the measures are also presented visually in figure 6.9 as a marginal cost curve. The x-axis denotes the exposure-reduction potential of each measure, and the y-axis indicates the cost of the measure per unit of exposure reduction—that is, million $ per year per μg/m³ reduction in population-weighted ambient $PM_{2.5}$ in the GDA. The curve starts from the right at the baseline exposure of 84 μg/m³ with the measures in increasing order from the lowest to the highest marginal cost. The blue curve represents the measures that can be implemented within the GDA. The red and green curves are discussed in section 6.4.3.

Some measures can improve air quality and deliver net cost savings. These measures are shown below the zero-cost line and have negative marginal costs, resulting in net cost savings to the society. The revenue from some municipal waste management options (for example, from the sale of recycled materials and landfill gas) outweighs the cost of separation, collection, and managed landfills of the waste. Similarly, the savings from more efficient energy use of modern brick kilns compensate for upfront investments. For the GDA, this analysis reveals improved municipal waste management in urban and rural areas—that is, separation and collection of waste, centralized composting of food waste, recycling of paper and wood waste, and incineration of plastic and textile waste with heat recovery—as cost-saving options that can reduce waste burning and landfill gas emissions and contribute to improved air quality. Furthermore, complete replacement of current brick kilns with modern facilities (which is beyond what is already planned in the current legislation) will result in net cost savings, considering the savings in fuel costs. Together, these measures could reduce ambient $PM_{2.5}$ exposure in the GDA by more than 9 μg/m³ at a net saving of $132 million per year.

Low-cost options include regular inspection and maintenance (I&M) of road vehicles and ban on open burning of agricultural waste albeit with relatively limited $PM_{2.5}$ exposure reduction potentials; improved PM and NO_x controls at power stations in the GDA with estimated exposure-reduction potential of 4.3 μg/m³; universal access to clean cooking fuels (LPG and electricity) to eliminate solid-fuel use in households with reduction potential of 9.7 μg/m³ as well as elimination of exposure to household air pollution; and road paving, street washing, and water spraying which could reduce $PM_{2.5}$ exposure from road dust and construction activities by about 3.8 μg/m³. However, experience in some Asian countries does not confirm the benefits of road washing for $PM_{2.5}$. Together, these options could improve exposure by 19 μg/m³ at a cost of less than $6 million per μg/m³ per year with a total cost of $110 million per year.

Control measures of moderate cost could reduce exposure by another nearly 10 μg/m³. These include more efficient PM controls at steel-rerolling plants and other industry PM controls, and the use of low-sulfur (0.5 percent sulfur) oil for SO_2 control in power plants. The cost of these measures is estimated at $22 million per μg/m³ per year with a total cost of $212 million per year.

The control measure with the highest marginal costs is PM controls from non-road mobile machinery (shipping and agriculture). This measure could reduce exposure by 0.76 μg/m³ at a cost of $95 million per year.

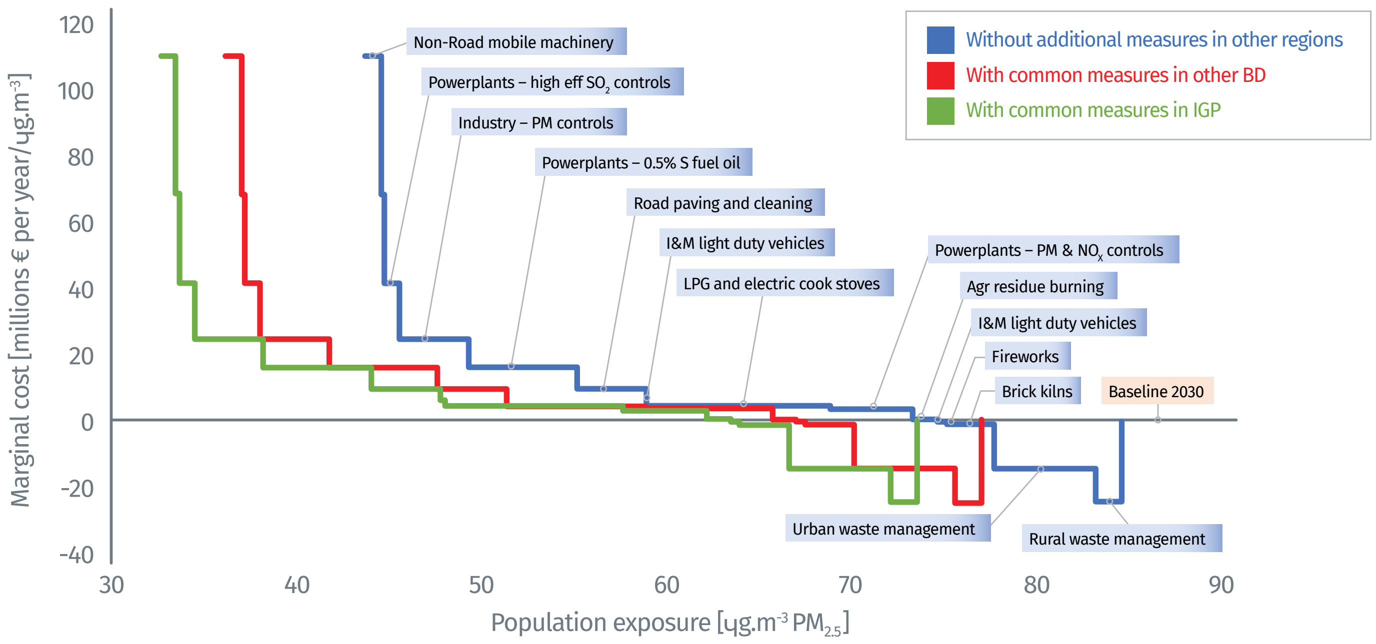
Additional control of SO_2 emissions from power plants in the GDA could reduce ambient $PM_{2.5}$ by another 0.9 μg/m³ on top of the 5.7 μg/m³ reduction from the use of low sulfur (0.5 percent sulfur) oil. The cost of this additional control measure is uncertain and is therefore discussed in section 6.4.4.

Table 6.4 Cost of population-weighted ambient $PM_{2.5}$ exposure reduction in GDA

Emission-control measures (groups)	Potential exposure reduction (μg/m³)	Marginal costs (million $ per μg/m³ per year)	Total costs (million $ per year)
Rural waste management	1.44	-28	-40
Urban waste management	5.43	-16	-89
Brick kilns: Switch to modern technologies	2.55	-1.1	-2.7
Fireworks: Ban	0.29	0.0	0.0
Regular I&M of heavy-duty vehicles	0.20	0.3	0.1
Agricultural waste burning: Ban on open burning	1.24	0.7	0.8
Powerplants: PM and NO_x controls	4.40	3.9	17
Cook stoves: Switch to LPG or electric	9.66	5.1	49
Regular I&M of light-duty vehicles	0.15	6.3	1.0
Road dust: Paving and street washing	3.77	11	42
Powerplants: SO_2 controls (0.5% S)	5.69	19	106
Industry: Improved PM filters	3.75	28	106
Inland shipping and agricultural machinery	0.76	125	95
Total	**39.3**	**7.3[a]**	**285**

Source: World Bank analysis.
Note: [a] Average marginal cost of all measures

Figure 6.9 Marginal cost of population-weighted ambient $PM_{2.5}$ exposure reduction in GDA



Source: World Bank analysis.

The cost-effectiveness analysis presented above is restricted to the potential from technical emission-control measures that are usually discussed in air quality management. However, further air quality improvements could be achieved by additional measures that are beyond the conventional responsibilities of air quality managers. Energy-efficiency improvements and the enhanced use of cleaner fuels such as renewable energy could reduce the need for end-of-pipe emission controls. Transport policies addressing alternative options for mobility, such as public and nonmotorized transport, could alleviate the urgency of controlling vehicle emissions. Agricultural policies dealing with modern forms of agricultural practices are also important, including manure management and fertilizer use that all are important sources of $PM_{2.5}$ precursor emissions. Importantly, behavioral changes can affect the demand for motorized mobility, consumption levels, cooling needs, and meat production, all with impacts on air pollutant emissions, air quality, and public health. Integration of air quality concerns into these sectoral policies could deliver multiple benefits on different policy priorities and reduce the cost of pollution controls compared to narrowly focused air quality policies. Thus, the cost figures derived in this analysis should be seen as conservative estimates, since they do not consider cheaper approaches that deliver benefits for multiple policy objectives.

6.4.3 Benefits from regional cooperation

The measures in table 6.4 and the blue curve (GDA interventions) in figure 6.9 are not sufficient to reach WHO's Interim Target 1 of 35 µg/m^3. The target may be achieved either by increasingly expensive control measures from sources in the GDA or by emissions reductions elsewhere in Bangladesh (red curve) and the IGP airshed (green curve).

The GDA is embedded in the IGP airshed and thus affected by significant transport of pollution from outside the GDA, with 40 percent of ambient $PM_{2.5}$ caused by emissions originating elsewhere in Bangladesh and in other countries. Any measures within the IGP airshed will therefore reduce pollution in the GDA, and thereby help the GDA in reaching adequate air quality targets and in reducing the need for adopting the most expensive measures. Vice versa, other regions in the IGP airshed will benefit from action taken in the GDA.

To explore the interdependencies of air quality management within the IGP, two scenarios are examined in which other IGP regions would adopt and implement a common set of emission-control measures (ref. red and green lines in figure 6.9 above and table 6.7). These sets comprise low-cost measures that emerged prominently in the World Bank Study for South Asia (World Bank 2022a), recent cost-effectiveness analyses for Uttar Pradesh and Bihar and ongoing work for GDA, Bangladesh and Eastern IPG.

Scenario 1 assumes that these measures will be applied in other regions in Bangladesh outside the GDA (red line). In 2030, this would reduce ambient $PM_{2.5}$ in the GDA by about 7.5 μg/m³. The second scenario (green line) examines the implications for the GDA if the common set of measures were implemented throughout the IGP, particularly in Eastern IGP. This would deliver another 3.5 μg/m³ improvement in ambient $PM_{2.5}$ the GDA. About half of this reduction potential is linked to emission controls in the neighboring Indian state of West Bengal. The remainder is associated with measures in the more distant Indian states of Bihar and Uttar Pradesh, for which prevailing wind patterns cause a considerable impact on air quality in the GDA.

These scenarios result in a leftwards shift in the marginal cost curve for the GDA in figure 6.10. On its own, the GDA could achieve ambient $PM_{2.5}$ of 45 μg/m³. With common measures implemented in the rest of Bangladesh, ambient $PM_{2.5}$ could be reduced to 37.5 μg/m³, still above the WHO Interim Target 1. With common measures implemented throughout the IGP, ambient $PM_{2.5}$ could decline to 34 μg/m³ and thus enable the GDA to achieve the WHO Interim Target 1 of 35 μg/m³.

6.4.4 Cost-benefit analysis of emission control measures

Annual deaths from $PM_{2.5}$ exposure in the GDA are estimated at 23,750 in 2019. Annual deaths rise to 27,500 in 2030 mainly due to population growth. These estimates are from exposure to both ambient $PM_{2.5}$ and $PM_{2.5}$ household air pollution from the use of solid fuels for cooking. They are based on population-weighted ambient $PM_{2.5}$ of 84 μg/m³ in 2019, and, without comprehensive measures to control $PM_{2.5}$ air pollution, 84 μg/m³ in 2030. Estimated annual deaths are 15 percent of deaths from $PM_{2.5}$ in all of Bangladesh (see chapter 2 and appendix 2). This is proportional to the share of the Bangladeshi population living in the GDA. While ambient $PM_{2.5}$ is substantially higher in the GDA, the share of the population using solid fuels and thus exposed household air pollution is substantially lower than in Bangladesh as a whole.

Implementing the 13 groups of emissions control measures presented in table 6.4 is estimated to reduce population-weighted ambient $PM_{2.5}$ from 84 to 45 μg/m³ (blue curve) and eliminate the use of solid fuels for cooking in the GDA. This is estimated to reduce deaths from $PM_{2.5}$ exposure in the GDA by 8,500 in 2030 from 27,500 to 19,000.[60] This is a 31 percent reduction in annual deaths. Reduction in illness is of similar magnitude. Further reducing population-weighted ambient $PM_{2.5}$ to the WHO Interim Target 1 of 35 μg/m³ by undertaking emission control measures in other parts of Bangladesh and regionally as discussed in section 6.4.3 will reduce deaths in 2030 by an additional 4,200.

The health benefits—or reduction in deaths and illness—in the GDA from reducing population-weighted ambient $PM_{2.5}$ from 84 to 45 μg/m³ are valued at $35.87 billion over a period of 20 years from the time of implementation of the control measures. This is estimated by applying the methodologies in appendixes H and I. The cost of the control measures over the same time period is $3.56 billion. This gives a benefit-cost ratio (BCR) of 10.1 for the set of emission control measures in table 6.4.

A provisional estimate of the impacts of measures taken in the GDA on population exposure in areas outside the GDA—that is, in the rest of Bangladesh and in neighboring countries has been derived with the GAINS model. For the measures listed in table 6.4, 58 percent of the overall reduction in population exposure occurs outside the GDA—that is, improvements in cumulative population exposure in downwind areas account for 138 percent of the improvement within GDA. This means that total exposure reductions throughout the IGP from measures taken in GDA are 2.4 times higher than the local benefits occurring within GDA. This is caused by the residence time of $PM_{2.5}$ in the atmosphere of about one week, during which GDA emissions move over typically 1,000 kilometers given an average wind speed of about 1.7 meter per second. On average, only the first 50 kilometers of this distance occur over GDA while the remaining distance affects other areas in Bangladesh and in neighboring countries. Thus, the BCR of the control measures taken within the GDA is 24.0 when accounting for the total benefits throughout the IGP airshed (table 6.5).

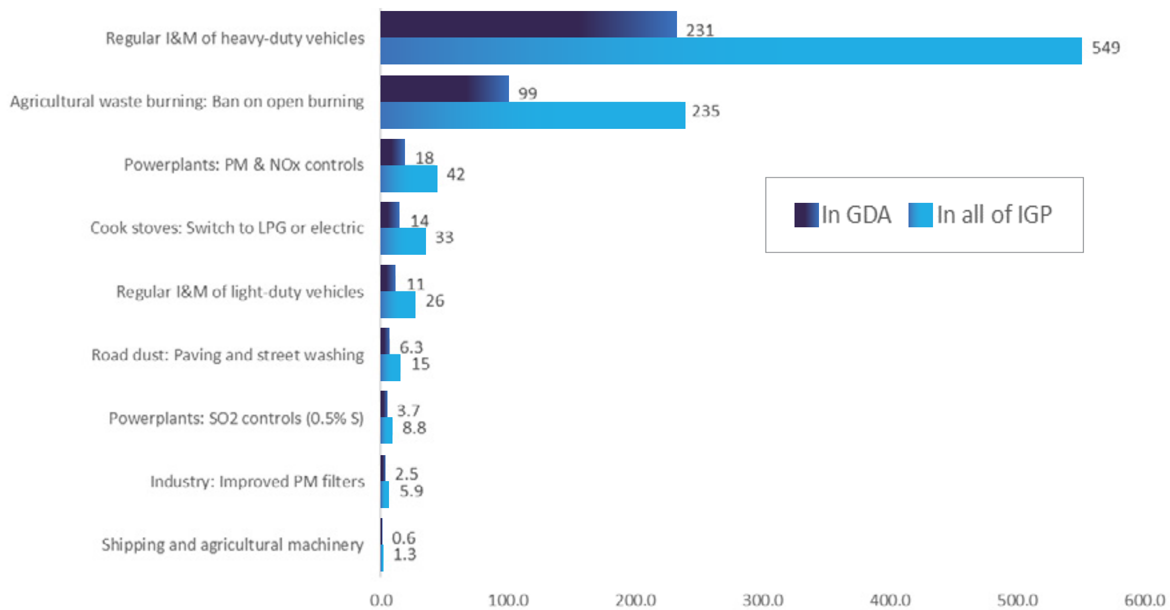
Table 6.5 Benefits and costs of $PM_{2.5}$ control

	In the GDA	In other areas in the IGP airshed	Total throughout the IGP airshed
Health benefits ($, billions)	35.87	51.9	85.42
Costs ($, billions)	3.56	n.a.	3.56
Benefit-cost ratio (BCR)	10.1	n.a.	24.0

Source: World Bank analysis.
Note: n.a. = Not applicable. Benefits and costs are for a period of 20 years. Future benefits and costs are discounted at an annual rate of 5 percent.

For the nine groups of control measures with costs greater than zero the BCRs range from 0.55 to 231 when only accounting for benefits within the GDA and from 1.32 to 549 when accounting for the benefits throughout the IGP (figure 6.10). The assessment indicates that the benefits of $PM_{2.5}$ control measures for inland shipping and agricultural machinery are just about half of the cost if only benefits within the GDA are accounted for but are 1.3 times the cost if benefits throughout the IGP are included. However, further analysis is required to determine how much of the benefits throughout the IGP accrue to Bangladesh and may show that the BCR for Bangladesh is less than one. Not implementing this measure is estimated to still bring ambient population-weighted $PM_{2.5}$ in the GDA to below the WHO Interim Target 1 of 35 µg/m³.

Figure 6.10 Benefit-cost ratios of $PM_{2.5}$ control measures in the GDA



Source: World Bank estimates.

Control measures addressing emissions in the GDA from cooking with solid fuels; solid waste; and power plants account for as much as 26.6 µg/m³ or 68 percent of the total population-weighted ambient $PM_{2.5}$ reduction potential. These control measures provide either net savings or BCRs of 3.7–18 when only accounting for benefits within the GDA and of 8.8–42 when accounting for benefits within the entire IGP.

The largest ambient $PM_{2.5}$ reduction potential in the GDA is from power plants. The reduction potential is estimated based on standard emission coefficients for primary $PM_{2.5}$ and NO_x and SO_2 emissions from the burning of high sulfur fuel oil with 3.0–3.5 percent sulfur content (percent S). The control measure in table 6.4 and figure 6.10 for reducing SO_2 emissions is switching to fuel oil with 0.5 percent sulfur (0.5 percent S). This removes around 85 percent of SO_2 emissions. The GAINS model estimates that this can reduce population-weighted ambient $PM_{2.5}$ by 5.69 µg/m³ in the GDA at cost of $106 million per year, as lower sulfur fuel is generally more expensive than higher sulfur fuel. The estimated annual cost is based on an incremental cost of $125 per ton of fuel oil and reflects fuel oil price differentials observed in the global markets in 2023.[61] The BCR at this incremental fuel cost is 3.7–8.8. However, the incremental fuel cost fluctuates with global supply and demand. Especially, the recent introduction of the global 0.5 percent sulfur standard for international shipping imposed by the MARPOL Convention of the International Maritime Organization (IMO) caused rather high price variability, which however is expected to stabilize after 2025.

Further SO_2 emissions reductions can be achieved by switching to 0.1 percent S rather than to 0.5 percent S fuel. The GAINS model estimates that this can reduce population-weighted ambient $PM_{2.5}$ by another 0.88 µg/ m³ in the GDA. The cost of this measure is, however, highly uncertain. As of mid-September 2023, the incremental cost of 0.1 percent S fuel versus 0.5 percent S fuel was around $300 per ton of fuel.[62] However, an international study assessing the economic consequences of the introduction of the recent IMO fuel quality standards projects that the incremental cost of 0.1 percent S versus 0.5 percent S fuel may settle at somewhat above $40 per ton of fuel (Cofala et al. 2018). The BCR for this range of incremental fuel cost is 0.22–1.69 if accounting for benefits only within the GDA and 0.54–4.02 if accounting for benefits in the entire IGP (table 6.6). The break-even incremental fuel cost (that is, BCR=1.0) is $68 per ton for benefits in the GDA only, and $160 per ton for benefits in the entire IGP. This means that switching to 0.1 percent S fuel instead of 0.5 percent S fuel in the GDA power plants will only provide Bangladesh positive net benefits if the cost differential declines from its current $300 to somewhere in the range of $68–160 per ton. Precisely where in this range depends on how much of the benefits in the entire IGP is within the borders of Bangladesh. This requires further analysis to answer.

An alternative option to low sulfur fuel at the GDA power stations is flue gas desulfurization (FGD). The cost-effectiveness and viability of this option requires an assessment of the specific technology of each power station (large stationary engines), the expected remaining life times of the stations, operating regimes (base load or peak power), availability and costs of large quantities of limestone in GDA, transportation infrastructure, options and costs for disposal or re-use of by-products, and so forth.

Table 6.6 Cost-benefit analysis of 0.1 percent sulfur fuel in oil-fired power plants in the GDA

	Low cost	High cost
Initial fuel oil (% S)	0.5%	0.5%
Control measure: Lower sulfur fuel (% S)	0.1%	0.1%
Incremental cost of fuel ($/ton) [a]	40	300
Total incremental cost ($, millions per year)	36	270
Reduction in ambient $PM_{2.5}$ (µg/m^3)	0.88	0.88
Health benefits in GDA per µg/m^3 ($, millions per year)	69	69
Health benefits in GDA ($, millions per year)	61	61
Benefit-cost ratio (BCR) within GDA	1.69	0.22
Total benefit-cost ratio (BCR) in the IGP airshed	**4.02**	**0.54**

Source: World Bank analysis.
Note: [a] Low cost is from from Cofala et al. (2018), and high cost is from https://shipandbunker.com.

6.4.5 Uncertainties

The accuracy of the emission estimates presented in this chapter is hampered by important gaps in critical data found to be essential for developing robust emission inventories in other countries. These include the paucity of geo-referenced statistics on the current levels of socioeconomic activities (for example, population counts, transport volumes, industrial and agricultural production, and waste-management practices). Some of the available data date back 10 years or more and do not provide a reliable picture of the current situation given the dynamic economic, social, and technological trends in the rapidly urbanizing region. Moreover, given the divergence of available emission estimates for brick kilns, it would be important to revisit data on locations, technologies, and production volumes of brick kilns, which should capture all kilns as well as the ongoing restructuring process of the industry over time.

Some of the key results from the source apportionment analysis reveal important new insights that might differ from long-held beliefs (for example, about the relative importance of some emission-source categories). Further validations of model outcomes could therefore increase trust in the results and thereby strengthen the basis for knowledge-based air quality management in the GDA. Although the number of air quality monitoring sites has increased in the recent past, there is still little information about $PM_{2.5}$ levels outside the Dhaka city limits. Furthermore, temporal gaps in monitoring data make it difficult to establish reliable annual mean concentrations for many monitoring stations. In addition, there are no data available about the chemical composition of $PM_{2.5}$ and its seasonal patterns. Such information, which is now being collected in other South Asia countries, would be extremely valuable for comparisons with model results computed for the different chemical species. Most importantly, such chemically speciated monitoring data would also enable alternative source-apportionment methods such as the positive matrix factorization (PMF) method (USEPA 2014). Outcomes could then be compared with model results.

While the results obtained from this first assessment of cost-effective measures to improve air quality in the GDA reveal the most important options for air quality improvements and the order of magnitudes of their potential air quality improvements in the GDA, a refined analysis will require improved input data.

6.5 Priority measures for cost-effective improvement of air quality in GDA

There is no single measure available in the GDA that alone could deliver clean air. A comprehensive AQM strategy therefore needs to develop an appropriate portfolio of measures that (a) delivers sufficient air quality improvements (for example, brings $PM_{2.5}$ exposure below a certain target such as the WHO Interim Target 1 of 35 μg/m³); and (b) is economically, socially, administratively, and politically acceptable. The available measures vary not only in their exposure-reduction potentials but also in their implementation costs to the entire economy, welfare costs to the society (considering the benefits of clean air), and financial costs to the economic sectors that would have to implement these measures. Measures will have different impacts on the net burden to the government's budget imposed by transfer payments such as investment and fuel subsidies. Furthermore, measures will differ in their ease of implementation and enforcement.

The cost-effectiveness analysis in this report focuses on the measures' economic costs and emission-reduction potentials, considering measures with a sizable potential for air quality improvements and low economic costs.

The following six source sectors emerge as priorities for emission controls mainly due to their large emission-reduction potential:

- **Power generation** contributed about 11.5 μg/m³ to total ambient $PM_{2.5}$ population exposure to in the GDA in 2020. Tight PM, NO_x, and SO_2 controls could reduce that by up to 11 μg/m³ in 2030. In 2019–2020, 37 percent (2,276 MW) of all powerplants in the GDA were operating with large stationary engines with heavy fuel oil—that is, Kodda, Gazipur, Madanganj, Meghnaghat, Nababganj, Siddhirganj, and Kanchan Purbachal, as well as Ghorasal (the latter also with natural gas)—with a sulfur content between 3.0 and 3.5 percent. Heavy fuel oil accounted for about 27 percent of total fuel consumption in the GDA powerplants. In addition, 500 MW (Keranigonj, Bramhangoan, and Aurahati) were fueled with high density diesel (0.5 percent sulfur). These plants caused about two thirds of all SO_2 emissions in the GDA. Several options are available to reduce these emissions. Use of low sulfur fuel oil, FGD or switching to natural gas could reduce ambient $PM_{2.5}$ exposure by up to 6.6 μg/m³ in 2030. Beyond the emission standards for power plants that have been established by the government in 2022, further tightening of requirements, especially for NO_x and PM (equivalent to Stage IIIB standards of the European Union) turn out as a cost-effective way forward for additional ambient $PM_{2.5}$ air quality improvements in the GDA of up to 4.4 μg/m³.
- **Households cooking with solid fuels** in the GDA is a major source of ambient $PM_{2.5}$ exposure. In addition, indoor exposure to $PM_{2.5}$ and gaseous emissions from solid fuels causes serious health impacts, especially in women and children. In 2020, an estimated 50 percent of rural and 5 percent of urban households in the GDA used solid biomass (wood/chalk/chopped wood, straw/leaves/bran/husk. charcoal/dried dung) as cooking fuel. With household cooking fuel consumption derived from the Bangladesh Demographic and Health Survey 2017–2018 (NIPORT and ICF 2020), emission factors from the scientific literature on studies performed in South Asia, and the GAINS atmospheric dispersion calculations it is estimated that solid fuel used by GDA households accounted for more than 12 μg/m³ of population exposure to $PM_{2.5}$ in 2020.

  For 2030, it is assumed as a baseline that without further policy interventions the number of households using solid fuel would remain at the current levels, while the share declines somewhat due to population growth and continuing urbanization. Providing universal access to clean cooking fuels—that is, to electricity (for example, induction stoves), natural gas, LPG, solar power, or combinations of these—would reduce $PM_{2.5}$ exposure in GDA by nearly 10 μg/m³ and eliminate the serious health impacts of indoor pollution from solid fuel use in households.

  In contrast, the replacement of traditional biomass cookstoves with improved cookstoves delivers far from optimal exposure reductions at higher costs. Thus, more would be required to achieve full exposure reductions than the current plans of the government to install improved cookstoves in 30 million households by 2030.
- **Management of municipal solid waste.** In 2020, managed and unmanaged centralized and decentralized burning of municipal solid waste in urban and rural areas in the GDA contributed about 7.5 μg/m³ to ambient $PM_{2.5}$ population exposure. Considering a further increase in the volume of municipal waste and the likely impacts of the 2021 solid waste management rules, measures that eliminate the open burning of solid waste could reduce $PM_{2.5}$ exposure in the GDA by up to 4.5 μg/m³ in 2030. Such measures must address the whole waste chains in urban and rural areas, from waste separation at the source, separate collection, recycling, and managed centralized disposal with the remaining fraction with collection and re-use of landfill gas. In particular, centralized composting of food and biodegradable waste as well as the recycling of plastic, paper, textile, and glass appear as a very cost-effective options.

- **Enhanced PM controls at large industrial sources** (for example, steel rerolling) could yield up to 3.8 µg/m^3 exposure reduction. More efficient PM filters, such as high-efficiency de-dusters and electrostatic precipitators with three fields applied to large industrial sources, emerge as a cost-effective option.
- **Reduction of road and construction dust** has a sizeable exposure-reduction potential of 3.7 µg/m^3. Water spraying at construction sites has been proven as an effective means. Lowering road dust (for example, through further road paving) is a more complex issue, and especially road cleaning (washing and sweeping), while showing positive results on the visible coarse fraction of particulate matter, has shown mixed results in other Asian countries with little impact on the fine fraction—that is, $PM_{2.5}$.
- **Modern brick kilns**, such as Hoffman and tunnel kilns, with the complete replacement of traditional brick kilns could deliver $PM_{2.5}$ exposure reductions of up to 2.6 µg/m^3. The government has recognized the importance of this source category and issued several road maps and regulations, which will show a positive impact in the future. However, ensuring the full adoption of modern technologies will be important.

Other options each offer smaller exposure reductions below 0.5 µg/m^3. Some of them are available at negative costs, where their upfront investments are compensated for by subsequent cost savings or revenues from the sale of by-products (for example, the collection and recycling of paper, textile, and plastic waste). Other options come at high economic costs, such as stricter emission standards for agricultural machinery and shipping.

For some sectors, the government has already issued regulations on emission standards which will show some effect in the future. However, the current regulations must be revised in most cases to achieve fundamental air quality improvements in the GDA.

6.5.1 The need for airshed-wide AQM

Primary and secondary $PM_{2.5}$ emissions from within each district in the GDA contribute only between 13 and 32 percent to total exposure in the GDA, so unilateral action of a GDA district can deliver only limited air quality improvements. However, 65 percent of ambient $PM_{2.5}$ exposure originates from emissions within the GDA. Thus, the measures emerging from this cost-effectiveness analysis must be implemented throughout all five GDA districts. The impacts of the various measures will differ due to differences in the emission-source structures across the five districts. For instance, universal access to clean cooking fuels will be more important in rural areas while, for example, reduction of road and construction dust is more critical in Dhaka city.

At the same time, 35 percent of ambient $PM_{2.5}$ in the GDA originates from sources outside the region. Thus, emission-control measures that could be taken within the GDA will not be sufficient to reach the WHO Interim Target 1 for $PM_{2.5}$ of 35 µg/m^3. Co-operation with other districts in Bangladesh and regions in the IGP in other countries is indispensable for achieving substantial air quality improvements in the GDA. At the same time, regionally harmonized strategies could alleviate the need to take the GDA's most expensive measures. Particularly important at regional IGP scale is the control of SPM, including agricultural sources (balanced fertilizer application and manure management). Such sources must be addressed to control formation of secondary $PM_{2.5,}$ that is mostly NH_3 emissions from imbalanced fertilizer use and livestock manure sources from outside GDA that reacts with SO_2 and NO_2 sources within GDA (power plants, industry, and transport), that is included in the list above.

The GDA's dependency on measures taken in areas surrounding GDA has also major implications on the perspective of how benefits from measures within GDA are seen. As revealed in section 6.4, about 58 percent of the total benefits of measures taken within GDA occur in downwind areas outside GDA—that is, in other regions of Bangladesh and in neighboring countries. Thus, a GDA-centric perspective that considers only local benefits suggests lower benefit-cost ratios than if the full benefits to the IGP airshed are included. Recognition of the full benefits of emission controls throughout the entire airshed is therefore an essential prerequisite for any common and coordinated air quality approach to air quality management across the IGP airshed can deliver substantial economic cost savings to GDA.

6.6 A way forward

As discussed in the chapter 3, Bangladesh has gradually enhanced its legal and institutional framework for AQM. Building on the Environment Conservation Act 1995, the Air Pollution Control Rules (APCR) 2022 sets national air quality standards based on WHO Guidelines Interim Goals, including a standard of 35 μg/m^3 for annual average of $PM_{2.5}$, and emissions limits and technical specifications for key sectors and industrial activities (for example, transport, power plants, brick kilns, construction work, incineration of municipal waste, cement, steel, textile, fertilizer, and pesticides manufacturing). The Rules expanded the coordination mechanisms and AQM leadership beyond the environment sector, by establishing the National Committee on Air Pollution Control (NCAPC). As a multi-sector decision-making body presided by the Cabinet Secretary, the NCAPC will coordinate the APCR implementation and instruct relevant agencies on specific interventions to comply with the new rules, including emergency measures depending on the levels of air pollution. To fully implement the APCR, the Government of Bangladesh (GoB) must develop a National Air Quality Management Plan (NAQMP), a Heavy Air Pollution Contingency Plan, and detailed guidelines and procedures for declaring air quality degradation of airsheds and developing management plans, publishing a list of highly air-polluting industries and activities, preparing prevention plans, and deploying monitoring and control systems. Other relevant regulations for AQM include the Brick Manufacturing and Brick Kilns Establishment Act 2013 (amended in 2019) and the Energy Efficiency and Conservation Rules 2016 (amended in 2023).

Despite the improvement in the AQM framework, Bangladesh's environmental management system remains focused on the environmental clearance process and based on command-and-control interventions. As recommended in chapters 3 and 10, the Government should (a) expand the range of policy instruments (for example, to market-based instruments that incentivize compliance of private sector with emissions standards), and (b) invest heavily in capacity building of environmental agencies and relevant units in line ministries, from developing specific technical guidelines, to staff training and automated monitoring systems. These measures would contribute to make both enforcement and abatement measures more efficient and effective. Additional analytical work is needed to ensure that future policies are based on reliable data. For that, the DoE needs to expand its air monitoring framework, and continue developing evidence through emissions inventories, chemical composition and source apportionment studies, and emission projections.

The Government plans to compile all these measures in the NAQMP. The latter will set forth coordinated multi-sector actions to reach WHO $PM_{2.5}$ interim targets by 2030. With the support of the World Bank, the DoE is designing the NAQMP to cover (a) interventions to improve overall AQM, air quality monitoring, establishment and maintenance of a national emission inventory, and the carrying out of source-apportionment studies; (b) cost-effective interventions (including policies and investments identified in the chapter) and time-bound targets in multiple sectors to control outdoor and indoor air pollution; and (c) mandates and responsibilities for implementation, and mechanisms for continuous stakeholder consultations and monitoring and evaluation. Additionally, MoEFCC plans to establish a Monitoring, Reporting, and Verification (MRV) framework to allow for reporting of emissions or emissions savings of short-lived climate pollutants (SLCPs; especially black carbon and methane).

Through the Bangladesh Environmental Sustainability and Transformation (BEST) Project, under implementation, the GoB is expected to (a) improve environmental-management capacity through regulatory and institutional reforms; enhance the regulatory capacity of the MoEFCC and the DoE; deploy advanced environmental monitoring, analytical, and information technology (IT) infrastructure; and (b) explore new green financing mechanisms and public-private partnership arrangements to promote private-sector participation in green investments over the long run.

In parallel, the GoB has requested World Bank support for a new air quality operation, as part of the upcoming Regional Air Quality Program for the Indo-Gangetic Plain and Himalayan Foothills (IGP-HF) countries (Bangladesh, India, Nepal, Pakistan, and most likely Bhutan). (For related information, see table 6.7.) As seen above, GDA and Bangladesh can only achieve its own air quality standard for $PM_{2.5}$ of 35 μg/m^3 by ensuring positive spillovers from air quality improvements in neighboring countries. Regional outputs under this engagement could further benefit and support Bangladesh's progress toward its AQM goals. This regional activity could result in additional financing to (a) establish the national emissions inventory and source-apportionment studies; (b) implement the MRV system for tracking SLCPs; (c) enhance AQM capacity in key sectors through technical specifications for controlling emissions, standard procedures for line agencies, training, and awareness campaigns; and (d) design policy instruments (for example, fiscal incentives for green technology). Additionally, the potential operation would finance abatement interventions in targeted sectors, such as energy, agriculture, brick kilns, and transport (to be selected during project preparation).

Table 6.7 Common set of air pollution control measures assumed in the cooperative scenarios for the other IGP regions

Mobile sources:
• Effective inspection and maintenance for heavy-duty and light-duty road vehicles
• Street paving and washing
Power generation:
• Stationary generators: Stage 3B controls
Households:
• Universal access to clean household fuels for cooking (LPG/electricity) to replace biomass fuels (fuelwood, dung)
• Residential kerosene lamps: Switch to LPG or LEDs
• Diesel generators: Stage 3B controls • Filters for restaurant kitchens • Electric cremation • Ban on fireworks • PM controls of commercial heating boilers • New/improved heating stoves burning solid fuels in households
Industry:
• Brick production: Zigzag kilns (55% of production capacity) and vertical shaft brick kilns (VSBK) with basic dust control (40% of production capacity)
• Electrostatic precipitators at large industrial sources • Basic NO_x controls for industrial boilers • Electrostatic precipitators at industrial furnaces • High-efficiency de-dusters (3-fields) in aluminum production • Flue gas desulfurization of large industrial boilers and furnaces • Basic SO_2 controls (-50%) at cement, aluminum, steel plants, and refineries
Agriculture:
• Efficient urea fertilizer use
• Stop open burning of agricultural residue

Source: World Bank.

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Endnotes

60 This is a 31 percent reduction in annual deaths and is less than the 47 percent reduction in ambient $PM_{2.5}$ exposure because of the concavity of the integrated exposure-response (IER) health risk functions (see appendix B).

61 See fuel oil price data at https://shipandbunker.com for VLSFO (maximum of 0.5% S) versus IFO380 (maximum of 3.5% S).

62 See fuel oil price data at https://shipandbunker.com for LSMGO distillate (maximum of 0.1% S) versus VLSFO (maximum of 0.5% S).

CHAPTER 7. CGE ANALYSIS OF GREEN POLICIES IN BANGLADESH

7.1 Introduction

Shifting Bangladesh's development model towards green growth requires environmental health and pollution management policies that are economic, social, and environmentally sustainable. In parallel, channeling financing and policy reforms to green growth can create a multiplier effect: reviving the economy, investing in projects to help Bangladesh prepare for the impending challenges of climate change while creating jobs, promoting low-carbon infrastructure, and building a more equitable society. This chapter analyzes the economic impact of alternative policies in Bangladesh for the pursuit of green growth objectives such as improved environmental quality and comprehensive human and social development. For the experiments, the policies were broadly based on fiscal interventions (taxes and subsidies), carbon market arrangements (carbon offsets) and public investment. The interventions were selected because of their potential to reduce air pollution and inadequate water supply, hygiene, and sanitation (WASH), two of Bangladesh's environmental priorities and foundational steps towards green growth.

7.2 Methodology

To address the challenge of investigating their possible direct and indirect impact on a variety of stakeholders, the study adopts a methodology based on the estimation and use of a computable general equilibrium (CGE) model. This model, the World Bank CGE Bangladesh Bioeconomic 101 (BB101), includes several innovative features for policy analysis, such as regionalized natural and human capital accounts, and heterogeneous agents' behavior. It is based on a detailed estimation of a regionalized, environmental-extended social accounting matrix. Its solutions are used to produce impact estimates of the "as if" variety, that may give insights into the possible outcomes of the policy measures considered and their broad impact on Bangladesh economic, social, and biophysical environment. While estimates of parameters and exogenous variables are used to construct the model and its experiments, model simulations produce forecasts of the impact of the policies analyzed conditional to the estimates of the parameters and the exogenous variables used. Following the pattern of causal analysis, BB101 is not designed to predict actual values of endogenous variables. The model is developed "to systematically explore possible counterfactual scenarios, grounded in thought experiments—what might happen if determinants of outcomes are changed," and forecast "the impacts of interventions (constructing counterfactual states associated with interventions) never previously implemented to various environments, including their impacts in terms of well-being" (Heckman and Pinto 2022, pp.3 and 11).

The main advantages of these typologies of CGE model with respect to alternative analytical tools, such as econometric studies or statistical impact analysis, are their sound economic basis and their flexibility to incorporate changes in parameters and endogenous variables. Further advantages include the ability to (a) estimate shadow prices that better reflect true (social) values of market and non-market services; (b) develop full value-added accounts including natural resources; (c) estimate net benefits of alternative policy decisions on the use of natural capital, relative to a counterfactual; and (d) model the economy-wide effects of sudden shocks (for example, climate disasters) that destroy natural and produced capital. The wide use of CGE and associated Social Accounting Matrix (SAM) for a variety of country analyses and specifications (Perali and Scandizzo 2021; Scandizzo and Ferrarese 2015) also makes it possible to carry out intercountry comparisons and useful benchmarking exercises.

The BB101 model is based on an extended SAM that comprises the following regional disaggregation:

- **Central region,** which corresponds to the Dhaka division. This region is characterized by the most urbanized and industrialized areas of the country. According to the plan the main policy actions in this region will be enhancing water security and water use efficiency and regulating and monitoring industrial and water pollution.
- **South region,** which includes the coastal zones characterized by floods and pressure on drainage capacity of coastal delta (Barishal, Chattogram and Khulna districts, Chattogram hills tracts, and part of the river system and estuaries).
- **North region,** which corresponds to the rest of the country (basically the northern divisions of Rangpur, Rajshashi, Maimansingh, and Sylhet). This region includes the Barind and drought prone areas, characterized by drought and freshwater availability, and Haor and Flash Flood areas characterized by food insecurity due to longer period of annual flooding (eventually the region could be further divided according to these two hotspots).

The BB101 model has been built as the final step of an integrated system of sequential modules that proceeds from the construction of a database with all data needed (economic, social, and biophysical) to construct an environmentally extended SAM and CGE, and to a gradual buildup of various interdependent blocks. The first stage of the sequence consists in compiling the database from national accounts, economic and social statistics, and previous estimates of SAM and CGEs for Bangladesh. The second stage is the construction of the biophysical model to estimate and predict the levels of biological and physical factors driving the key processes studied in the economic model. In a third stage, this model is integrated into a system of bridge matrices (BMA) that are capable of transforming biophysical estimates directly and interactively into parameters of an underlying SAM and of a corresponding CGE. The BMAs include the data sets by year and geographic location of each variable (for example,, agricultural yields and prices, forest fires, health damages and so forth) and the functions mapping them into estimates of SAM coefficients and/or model parameters.

7.2.1 Model simulations and their characteristics

The simulations performed with the model are comparative static experiments, where the CGE module produces a new general equilibrium solution after the equilibrium of a reference scenario has been perturbed by an exogenous shock. The new equilibrium yields endogenous quantities and prices for all domestic variables and endogenous levels of exports and imports for all traded variables for a projected scenario over ten years (in order to stress the fact that the simulation is not a forecast, the year of projection is indicated with T+ 10 where T is 2017 as the base year). Both the reference scenario (BAU) and the policy scenarios are obtained by solving the model under appropriate hypotheses on investment, export demand, international prices, and other exogenous variables. Consistency with World Bank macroeconomic projections across parameters overtime is achieved through model calibration within the chosen time horizon of ten years.

Basically, two types of experiments can be performed to (a) run the model for the base year under different assumptions on parameters and exogenous variables; and (b) project the base year to a given time horizon (for example, T+10) to obtain a reference solution (indicated as business as usual or BAU) to compare with the results of perturbing it with exogenous shocks. The first type of experiment essentially validates the model against the historical record and tests its performance with respect to different parameters and assumptions. It also establishes a benchmark against which changes can be evaluated. The second set of experiments enables the model to address more directly the impact of different policy instruments, by computing the quantity and price adjustments necessary to reconstitute the balance between demand and supply computed for the year of model calibration (the base year), disturbed by the exogenous shocks and compare these results with a reference solution. This solution in turn is obtained by constructing a counterfactual scenario of business-as-usual equilibrium, consistent with the World Bank macroeconomic model projections, for the same time horizon. Within this dual framework, in addition to model validation using the data base assembled, the calibration runs for the base year (2017), and the simulations to obtain the reference scenario, five sets of experiments were attempted and are reported below[63]: These experiments can be briefly described as follows: (a) the removal of energy subsidies; (b) the imposition of carbon taxes (c) different redistribution policies associated to government revenues generated by (a) and (b) policies; (d) the financing and implementation of two investment programs; (e) alternative combinations of the different measures in (a) through (d).

7.3 Model experiments of energy-subsidy removal

7.3.1 Main results

Basic economic theory suggests, and several recent studies have demonstrated that energy subsidies are harmful for economic development for two distinct reasons: (a) they reduce economic efficiency by determining a gap between private and social costs, and (b) they are inequitable because they are largely absorbed by richer consumers with an important share of the population still lacking access to modern energy services.[64] Economic efficiency is mainly reduced by price distortions and longer term unsustainable fiscal burdens. By fueling energy overconsumption, energy subsidies may also tend to aggravate a series of harmful externalities produced by anthropogenic interaction with the environment and sabotage the efforts to reduce air pollution, greenhouse gas (GHG) emissions and mitigate climate change.

To understand the subsidy mechanism in Bangladesh, consider that for electricity, the consumer price is set at a level below its long-run marginal cost of production and this gap is closed by a government direct budget subsidy to the Bangladesh Power Development Board (BPDB), which is responsible for supplying electricity in the country. This subsidy to the BPDB was almost

$1,200 million in 2015 (Sadeque and Bankuti 2017). A subsidy is also indirectly paid to gas and electricity, which is a primary user of gas for energy production, by setting the price of gas at a level below its opportunity cost, which according to ADB (2013) is one of the lowest in the world (In 2015, the average price of domestically produced natural gas in Bangladesh was $2.61/GJ). Because of the connection between the gas and the electricity prices, we examine the removal of the subsidies under the two alternative hypotheses that subsidies are phased out on both gas and electricity and the ensuing savings are (a) redistributed as lump sum payments to all households, or (b) redistributed as lump sum payments only to those below the poverty line.[65]

Three experiments were conducted on the removal of the subsidies. In the first experiment, the savings from the removal are not reinjected into the economy and thus increase the government fiscal balance. In the second experiment, the savings are redistributed through lump sum subsidies to the general population, while in the third the redistribution is only performed toward the people below the poverty line. In all cases, the subsidies removed include the subsidies explicitly given to reduce retail prices of electricity and those resulting from trade policies and translate into prices lower than opportunity costs for the electricity and gas consumers.

As table 7.1 shows, the removal of the subsidies leads to an increase in GDP at shadow prices in the scenario without the redistribution, mainly due to the increased efficiency in resource allocation[66]. These efficiency gains are estimated by comparing the GDP results of the scenario where the subsidies are removed, but not redistributed, with a BAU scenario at shadow prices—that is, at the prices prevailing after the removal and thus not distorted by the subsidies). However, a negative demand effect arises from subsidy removal under the assumption that the resources saved from discontinuing the subsidy are not being reinjected into the economy (the no redistribution scenario).

Table 7.1 Impact of the removal of energy subsidies on efficiency (cumulative Impact over 10 years) | *$, billions*

	BAU scenario (A) (T + 10)	BAU scenario (B) (T + 10)	Subsidy removal (C) (T + 10)	C - A	C - B
	At market prices (assuming a 6.5% annual growth rate)	At shadow (second best) prices			
Value added	2,665	2,585	2,572	-93	-13
Net indirect taxes	158	158	214	56	56
GDP	2,823	2,743	2,786	-37	43

Source: World Bank.
Note: GDP base year is 2017.

Tables 7.2 and 7.3 show the main results of the experiments in terms of values and physical indicators. In both redistribution experiments GDP increases compared to the BAU reference case, with the larger increase resulting for the case where all subsidy proceeds are redistributed to the poor.[67] All externalities[68] are also reduced and positive net social benefits (GDP minus value of externalities) prevail for both redistribution scenarios and are highest for the case of redistribution to the poor. For the externalities, the scenario with redistribution to the poor presents a lower environmental performance, with a smaller reduction of harmful externalities than the other scenario.

The impact on GDP is larger in the case of transfer to poor households because it translates into greater total expenditure, due to the higher propensity to consume of poorer households and lower price elasticities for basic goods. On the one hand, the increase in GDP is obtained by increasing output in less energy intensive sectors (especially services) and reducing output in more energy intensive sectors (electricity and transport services). On the other hand, the composition of production determined by the consumption increases of poorer households is more energy and water intensive—see, for example, the data in Barnes et al. (2011); this is especially so in the South and Dhaka.

These differences translate also into a lower reduction of harmful externalities, and more frequent and greater price increases in the case of redistribution to the poor. In both simulations, the removal of energy subsidies results in a significant surge in energy prices, with electricity costs, for instance, experiencing a notable 54 percent increase. This price hike leads to a reduction in consumer demand for energy, which subsequently affects energy production and distribution, facilitated by utilities.

This ripple effect reverberates throughout the value chains, causing energy-intensive sectors across the economy to contract. Since the most energy-intensive industries are also the most polluting, this overall contraction results in a net decrease in emission levels. Not only do electricity prices grow more under this redistribution assumption, but so do also the prices of items such as textiles, transport, and construction, especially in the North, with a corresponding decline in production of energy and energy intensive activities. On the other hand, the transfer to the poor policy appears to cause a greater reduction in the growth of energy intensive activities, along with a surge in production of many agricultural and service sectors, including education, public administration, health, and community services. Overall, the price impact in the transfer to the poor scenario appears to be either neutral or favorable for consumers, with the consumer price index unchanging (with respect to BAU) in the North and decreasing in Dhaka and the South.[69]

Table 7.2 Impact of Subsidy Removal (higher or lower annual increases than the BAU from the baseline)

	Energy subsidy with general redistribution (%)	Energy subsidy with redistribution to the poor (%)
Total GDP	2.40	4.34
Total value of external damages	-12.36	-8.10
Carbon emission	-3.47	-1.38
Mortality and morbidity due to inadequate WASH and to air pollution	-14.48	-9.70
Forest losses and sector damages	-1.14	-0.30

Source: World Bank.

Table 7.3 Impact on externalities (lower annual increases than the BAU from the baseline)

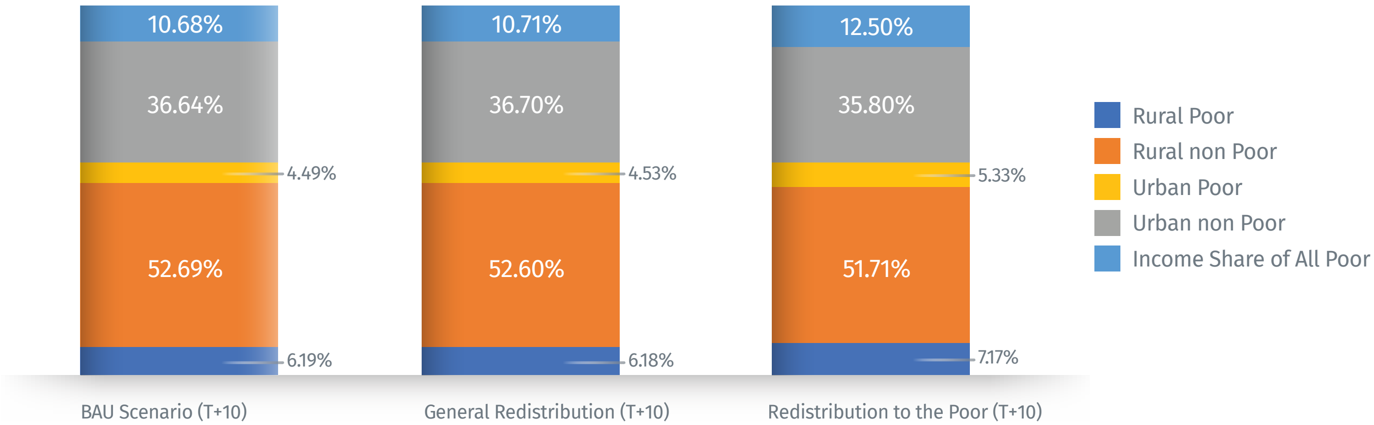
	Energy subsidy with general redistribution (%)	Energy subsidy with redis-tribution to the poor (%)
Mortality due to inadequate WASH (number of premature deaths)	-15.63	-15.92
Mortality due to air pollution (number of premature deaths)	-15.62	-8.81
Morbidity due to inadequate WASH and to air pollution	-11.97	-6.99
GHG emissions (million tCO2eq)	-3.47	-1.38
Flood damages in agriculture (Ha)	-1.58	-1.97
Forest losses (Ha)	-1.14	-0.3

Source: World Bank.

The results also suggest that the increase in GDP is dominated by the increase in net government revenue due to the removal of the subsidies. This increase in turn is translated into income increases through the redistribution policies hypothesized. The macroeconomic effects of subsidy removal would be contractionary, at least in the short run, despite its positive effect on efficiency, (at least if evaluated at market prices) if the government were to retain the savings from the subsidy removal but would turn expansionary under both redistribution hypotheses. The subsidy could have a positive impact on economic growth even without redistribution because it could increase government revenues. This could lead to several positive effects, such as easing the burden of government debt on future generations and keeping the public budget on a sustainable course. These effects were indirectly measured by performing a series of experiments giving government revenue a weight greater than private consumption, as in cost-benefit analysis. The results show that the impact of the subsidy on GDP at market prices would be positive if the weight of government revenue with respect to private consumption were to be greater than 1.7. This amount would reflect the value of one additional unit of government revenue, either in terms of the public goods and services that the government can provide, or in terms of the opportunity cost of one additional unit of taxation or public debt.

On the household income side, removal of the subsidies would improve incomes of all households (figure 7.1). Redistribution to the poor would be mainly paid by the non-poor income groups and by a deterioration in the foreign balance, while the government would see a further increase in its revenues despite its foregoing the proceeds from the subsidy removal. The distribution impact of the subsidy removal would be uniformly positive in the case of redistribution to the poor, with a larger income share for both rural and urban poor in all regions, while a general redistribution would have a small but regressive effect. This result is an indication that the subsidy removal would tend to have a regressive impact unless it were complemented with policies of income transfer to poorer households.

Figure 7.1 Impact of subsidy removal on income distribution: Household income shares by household group



Source: World Bank.

7.3.2 Lessons from the subsidy-removal experiments

The subsidies removed include those explicitly given to reduce retail prices and those resulting from trade policies and translate into prices lower than opportunity costs for the electricity and gas consumed. In particular, the model simulates a realignment of the electricity subsidized price and of the retail price of natural gas with its imported price (at the 2017 level) through an equivalent tax. The main results obtained from these experiments can be summarized in the following points:

- Removing subsidies would be beneficial for the economy as a whole, because it would lead to more efficient resource allocation and increased government revenue. The negative impact on private incomes and employment would be more than offset by the potential benefits of increased government revenue and its reinjection into the economy for investment expenditure or income transfers.
- The increase in government revenue could be used to improve total well-being in a number of ways, such as by redistributing it to households or investing it in public goods. Without any reemission of government revenue, the aggregate effects on the economy would only be positive if government revenue were considered to be worth more than 1.7 times private consumption.
- Phasing out subsidies would also yield aggregate benefits by reducing harmful externalities. These effects are large and consistent across different scenarios of redistribution.
- One possible reemission policy would be to redistribute government savings from the subsidy removal to all households. This would lead to both an expansion of the economy and a reduction of negative externalities.
- Another possible way to use the proceeds from subsidy removal is to redistribute them only to poor households. This would have a larger impact on the economy, but a smaller impact on reducing harmful externalities. However, this lower impact does not take into account the likely positive effects of the transfer on the substitution of more harmful cooking fuels. In any case, this policy would still lead to an improvement in net social benefit. This policy would also have significant and positive distributional effects, with a larger share of the gains accruing to the poor.
- Subsidy removal appears to have positive effects on income distribution only under the policy of redistribution to the poor. This scenario would lead to the highest performance in terms of GDP, net social benefits, and income distribution improvement, but the lowest one for the reduction of externalities.

7.4 Exploring the introduction of carbon-pricing instruments

7.4.1 Introducing a carbon tax: Features and the mechanism of action

A carbon tax at national level for Bangladesh would have the objective to enhance environmental awareness (both for CO_2 emissions and in general), and to price carbon in a way that reflects its (external) opportunity cost and helps shifting consumption toward the use of cleaner fuels. The main source of GHG emission in the country is the use of fossil fuel, which is increasing with economic growth and encouraged by generous government subsidies on electricity and gas. Because of strong economic growth, urbanization, and industrial expansion, GHG emissions in Bangladesh grew at an annual average rate of 7.2 percent over 1970–2016 and accelerated to 9.2 percent a year for the more recent years (2004–2016).[70] From a sectoral perspective, the power sector is the dominant emitter, but part of the responsibility falls on energy heavy users such as transport industry and even agriculture (with one of the largest power irrigation systems in the world).

The existence of large fuel subsidies to final and intermediate users, as examined in the first part of this chapter, implies that a rationalization of taxation based on carbon emissions of all sectors, that could accompany the institution of the carbon tax, would not only help to curb emissions, but also reduce market distortions. This operation, though difficult to carry out, could bring the so called "double dividend", given by the positive impact on the government finance without the deadweight loss that any taxation imposes upon the economy (Poterba 1989 Rausch et al. 2011). Distributional concerns derive from the fact that consumption of carbon related consumption goods of low-income households is a higher proportion of their income and display lower income and price elasticities. Lower income consumers could thus be the main losers from the first-round effects of the tax that would appear to impose a higher burden on their consumption budget relative to higher income households. However, several studies (see box 7.1) suggest that distributional effects are much more complex, and the prima facie negative effects on low-income households may be substantially mitigated or even reversed once lifetime incomes, factor returns, price and tax revenue distribution effects are considered.

Box 7.1 Recent studies on the introduction of carbon taxation

The distributional effects of carbon taxation have been the object of several studies (Bull, Hassett, and Metcalf 1994; Hassett et al. 2009; Metcalf 2007; 2019; Morris and Sterner 2013; Symons, Speck, and Proops 2002). However, perhaps not surprisingly, results appear to be diverse and to depend very heavily on circumstances, the openness of the economy and the distortions of the markets affected. Important factors are also the size of the tax and the way the proceedings are utilized and redistributed. The regressivity finding, which is present in many studies, tends to display large variations in magnitude. For example, Metcalf et al. (2008) finds that a carbon tax in the US would reduce the after-tax income of taxpayers in the first decile by 3.7 percent, compared to just an 0.8 percent reduction for the wealthiest decile, with the lowest figure referring to the incidence measurement in terms of lifetime income.

On the other hand, Gonzales (2012) and Hassett, Mathur, and Metcalf (2009) find that the indirect component of a carbon tax (that is, higher prices due to higher costs of production) is significantly more progressive, whereas the direct component, which focuses on the *prima facie* higher consumption costs for electricity of poor households, is regressive. Forward and backward linkages as well as timing are also relevant since the carbon tax can either fall forward in the form of higher consumer prices or backwards in the form of lower returns to factor inputs. The general equilibrium effects are thus complex and difficult to investigate without a reliable and comprehensive model. For example, although some studies—for example, Bovenberg and Goulder (2001) and Paltsev et al. (2007)—find that the short- and medium-term incidence of a CO_2 tax falls primarily on consumer prices, other general equilibrium studies—for example, Gonzales (2012)—showed that the final effect depends on how goods and factor markets react to the tax characteristics, its impact on labor and employment and on the way the tax is raised against consumption or production of CO_2.

Sources: Bull, Hassett, and Metcalf 1994; Hassett et al. 2009; Metcalf 2007; 2019; Morris and Sterner 2013; Symons, Speck, and Proops 2002.

7.4.2 Carbon-tax experiments

To assess the effects of a carbon tax, we have simulated the levy of a uniform tax on production across sectors, in proportion to their emissions. This approach is equivalent to levying a carbon tax directly on various fossil fuels, taking into account the carbon content of each fuel. This means that fuels with higher carbon content are taxed more heavily, reflecting their greater contribution to emissions, ensuring that each sector's tax burden is proportionate to its carbon footprint. To explore the benefits and costs of such a tax, along the most important dimensions of its impact, we performed three series of experiments: (a) a carbon tax ranging from $3 to $60 per ton of CO_2 emitted, raised across the board toward all producers, with no further reemission of the tax proceeds into the economy; (b) a carbon tax combined with a cap and trade system with the possibility of selling carbon credits for producers with emissions below a threshold level equal to the average unit emission (CO_2 per $ produced) in the economy, (c) a carbon tax with the same characteristics as in (a), but with redistribution of its proceeds to all households below the poverty line.

If a carbon tax is raised in proportion to the CO_2 emissions of a production activity, its effects will be similar to a targeted production tax, in the sense that it will change relative prices to incorporate the social costs of the carbon emissions. These costs concern not only carbon, through the global nature of climate change as a public good but include also those created by the association of carbon emissions with a host of harmful externalities, including $PM_{2.5}$ emissions, loss of biodiversity and risks of forest fires. These correlations are due to the fact that environmental degradation is a complex phenomenon that is at the same time the effect and the cause of a bundle of externalities. Thus, for example, forest fires tend to simultaneously increase GHG and $PM_{2.5}$ emissions, loss of biodiversity, and land degradation, thereby increasing the probability of more fires, higher degradation, and so forth. By better aligning individual incentives to social goals, carbon taxes may thus be used as a form of general environmental taxation addressed to a critical core of both global and local externalities.

7.4.3 A "pure" carbon tax on production

The results of the pure carbon-tax experiment show that, in the absence of a reinjection of its proceeds, a carbon tax would have negative consequences for the economy, even if it reduced harmful externalities. The tax would lead to a decline in GDP, which would not be offset by the avoided externalities (table 7.4). This would result in negative net local and global social benefits, for all tax rates considered. The beneficial welfare effects of the tax appear to have a maximum at a relatively low tax rate of around $3/ton. A reduction in the aggregate conversion factor (the ratio of market prices to shadow price index) is consistent with a steep linear increase in net social benefits. However, welfare effects at pre-tax prices are rather small and turn sharply negative above a $10/ton tax rate, while those at shadow prices are large and decrease slowly from a threshold of $5/ton.

The potential benefit of the tax boost in the public sector's balance can be examined by assuming that the government's income should be more heavily valued than private consumption (because of the tax burden associated with imposition of a tax). Under this assumption, the effect on GDP at market prices becomes favorable for every tax rate only when the value attached to government proceeds is at a minimum of 2.5 times that of private consumption. This threshold is notably higher than what's been estimated for the removal of energy subsidies, which is 1.5 times.

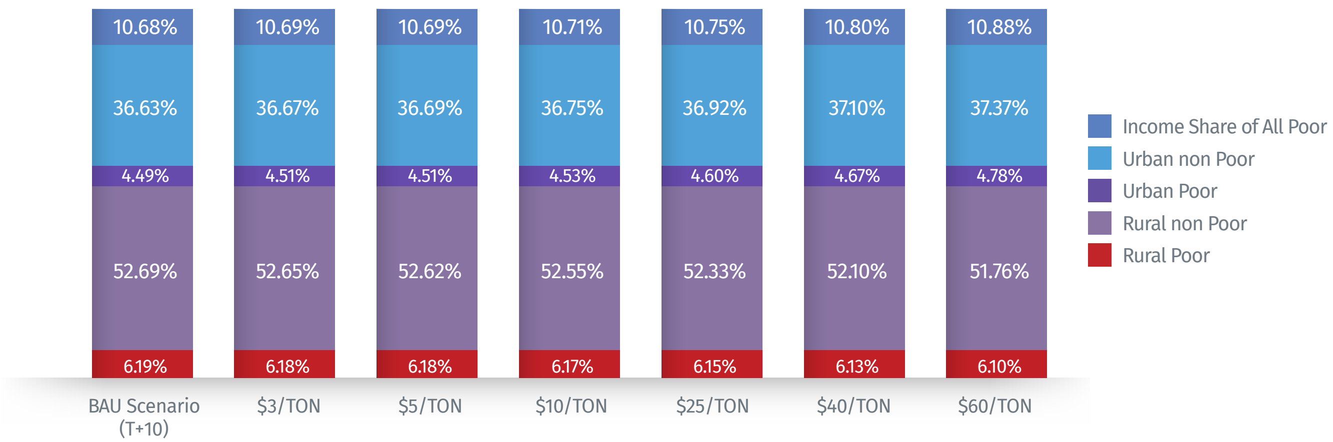
In terms of income distribution, carbon taxation appears to have only a slight positive impact, with the income share of the poor increasing uniformly with respect to BAU from 10.68 percent to 10.88 percent throughout the tax range (figure 7.2).

Table 7.4 Carbon-tax (Ctax) impact for different tax rates (higher or lower annual increases than the BAU from the baseline) | *Percent*

	Ctax$3/ton	Ctax$5/ton	Ctax$10/ton	Ctax$25/ton	Ctax$40/ton	Ctax$60/ton
Total GDP	-1.17	-1.95	-3.89	-9.69	-15.55	-23.83
Total GDP at shadow prices	22.63	21.85	19.93	14.18	8.37	0.15
Carbon emission	-0.84	-1.41	-2.84	-7.26	-11.95	-18.89

Source: World Bank.

Figure 7.2 Carbon-tax impact on income distribution: Household income shares by household group



Source: World Bank.

7.4.4 Cap-and-trade experiments

This experiment explores the possibility of reducing the negative efficiency effects of a pure carbon tax by using market forces. It is based on three components: (a) Producers are taxed based on the amount of CO_2 they emit per dollar of production. However, this tax only applies to emissions that exceed a predetermined limit, which is set at the average emission level for the sector. (b) This tax effectively acts as a penalty for producers who exceed the emission limit. Producers who successfully emit below the limit are rewarded with carbon credits, which they can sell to producers who exceed the limit. This creates a market-based incentive for compliance. (c) The experiment uses a specific type of carbon trading system through which producers can buy and sell carbon credits, based on the differences between their production and the limit fixed by the government, which give them the right to emit a certain amount of CO_2.

The experiment results suggest that this type of carbon trading system can significantly reduce emissions without having a major negative impact on economic efficiency. This is because the system allows producers to choose the most cost-effective way to reduce their emissions. Additionally, the system creates a market for carbon credits, which yields further efficiency benefits by expanding choices for producers. Overall, this experiment shows that carbon trading systems can be a more effective and efficient way to reduce emissions than traditional carbon taxes.[71]

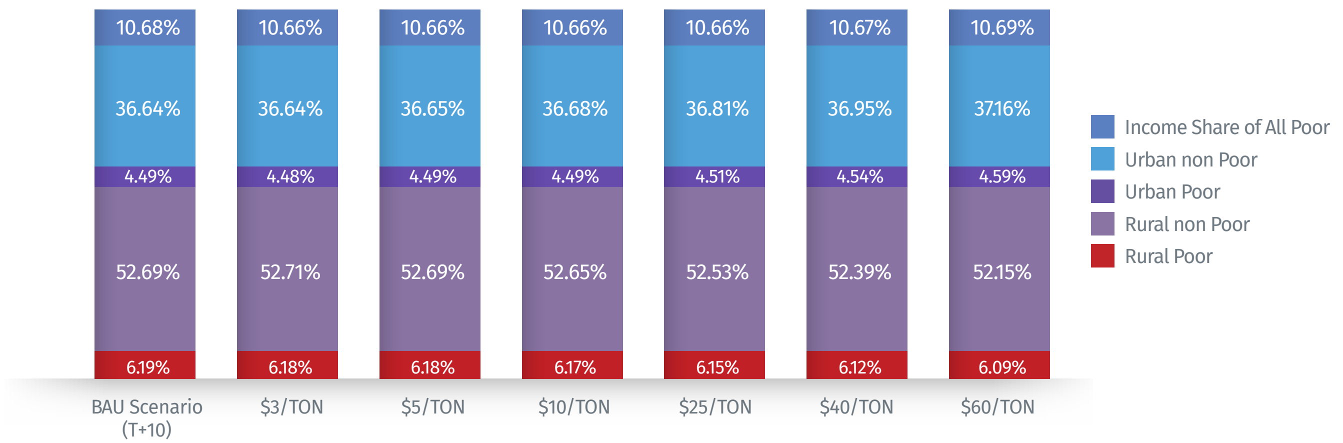
More specifically, the cap-and-trade policy experiment appears to be a winner for small values of the tax imposed on emissions above the threshold (for $3 and $5 per ton), in the sense that it both increases GDP and reduces externalities with a positive net balance for social benefits. However, carbon trading has the side effect of lowering the performance of the tax in reducing the negative externalities. This is in part the consequence of the fact that, at least for low levels of the tax, trading tax allowances neutralize the price effects of the tax both because of the expansionary effects of reinjecting resources into the economy and of the comparatively higher level of production that carbon trading allows for producers above the threshold (table 7.5). From the income point of view, improvements are registered for all households for the smaller values of the taxes, but income distribution remains stable throughout the whole range of possible taxes (figure 7.3).

Table 7.5 Carbon (Ctax) tax (with carbon trading) impact for different tax rates (higher or lower annual increases than the BAU from the baseline) | *Percent*

	Ctax$3/ton	Ctax$5/ton	Ctax$10/ton	Ctax$25/ton	Ctax$40/ton	Ctax$60/ton
Total GDP	0.75	0.47	-0.27	-2.85	-6.09	-11.79
Carbon emission	-0.41	-0.83	-1.89	-5.34	-9.22	-15.34

Source: World Bank.

Figure 7.3 Income distribution impact of different tax rates (with carbon trading) | *Percent of total income by household groups*



Source: World Bank.

7.4.5 Carbon tax with redistribution to the poor

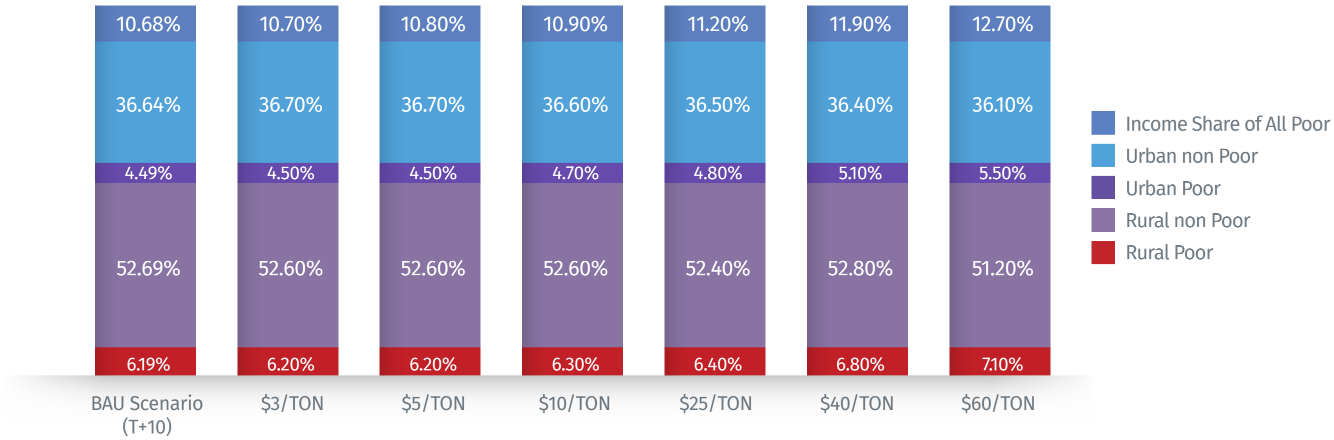
As a further enhancement of a carbon-tax measure, this experiment assumes that the proceeds of the tax are reinjected into the economy through lump sum payments to households below the poverty line. This policy combination displays net social benefits at shadow prices (but not at market prices) for all values of the tax, in the sense that it both increases GDP (at the second-best shadow prices under the cap-and-trade regime) and reduces externalities with a positive net balance for social benefits. Furthermore, the benefits from externality reductions grow more than proportionally with the size of the tax and increasingly overperform both the pure tax and the cap-and-trade scenarios (table 7.6). The impact on incomes is generally positive and increasing with the tax rate for the poor and negative for the non-poor. Income distribution improves progressively with higher tax rates, although it is only for the highest rates that the share of income of the poor undergoes a significant increase, both in absolute terms and in comparison, to the other two scenarios (figure 7.4).

Table 7.6 Carbon-tax (Ctax) (with redistribution to the poor) impact for different tax (higher or lower annual increases than the BAU from the baseline) | *Percent*

	Ctax$3/ton	Ctax$5/ton	Ctax$10/ton	Ctax$25/ton	Ctax$40/ton	Ctax$60/ton
Total GDP	-0.63	-1.06	-2.17	-5.76	-9.85	-15.97
Total GDP at shadow prices	3.41	4.35	4.16	2.91	6.21	8.19
Carbon emission	-0.63	-1.05	-2.14	-5.62	-9.50	-15.16

Source: World Bank.

Figure 7.4 Income distribution impact of different tax rates (with redistribution to the poor) | ***Percent of total income by household groups***



Source: World Bank.

7.4.6 Summary of above findings

The main results obtained from the carbon pricing experiments can be summarized as follows. Applying a carbon tax to production at a rate proportional to carbon emissions would have negative results on GDP at market prices, which would be almost completely countervailed by the values of externality reductions. However, social gains from a more efficient resource allocation and reduction of externalities are large and positive if market output is evaluated at shadow prices.

Income distribution effects of the standalone tax would be slightly positive, but overall, the tax would be macroeconomic contractionary and probably reduce the rate of growth of the economy, at least in the short run. In the medium-long run, increases in government revenues unmatched by reemission into the economy could have a beneficial effect on economic sustainability. However, sensitivity analysis shows that their contribution to the economy would have to be valued at more than 2.7 times as large as private consumption to outweigh the advantages provided by reinjecting the funds into the economy.

As in the case of the subsidy removal, the increase in government revenues represents a potential improvement in total well-being, which could be obtained under several different policies of reemission of the financial resources raised into the economy. The pure tax appears also to yield aggregate benefits by reducing harmful externalities and these effects are large and consistent across the different tax rate scenarios examined. A carbon tax combined with a cap-and-trade system appears to be neutral for income distribution, but successful from an efficiency standpoint.

The model simulations indicate that, at least for small values of the tax (for $5 and $10 per ton), this policy combination increases GDP and reduces externalities with a positive net balance for social benefits. However, carbon trading has the side effect of lowering the performance of the tax in reducing the negative externalities. This is because trading tax allowances tend to neutralize some of the price effects of the tax both through the expansionary impact of reinjecting resources into the economy and of the comparatively higher level of production (and emissions) that carbon trading allows for producers above the threshold.

A carbon tax combined with redistribution of its proceeds to households below the poverty line displays net social benefits at shadow prices (but not at market prices) for all values of the tax, in the sense that it both increases GDP (at the second-best shadow prices under the cap-and-trade regime) and reduces the externalities with a positive net balance for social benefits. Furthermore, the benefits from externality reductions increase more than proportionally with the increase of the tax and increasingly overperform both the pure tax and the cap-and-trade scenarios. This policy combination appears to have uniformly positive effects on poverty levels, with the share of income of the poor increasing in all regions. Income distribution improves progressively with higher tax rates, although it is only for the highest rates that the share of income of the poor takes a real leap both in absolute terms and in comparison, to the other two scenarios.

In general, model simulations suggest that a carbon tax will have a contractionary effect from a macroeconomic standpoint, at least in the short run[72], but this negative impact can be overcome by reinjecting resources into the economy either via a market mechanism (for example,, carbon trading) or through redistribution policies.

7.5 Water Investment Program

7.5.1 Structure of the program

The Bangladesh Delta Plan 2100 (BDP) Investment Program consists of a total of 80 projects: 65 are physical projects, and 15 are institutional and knowledge development projects at the first phase up to 2030. The BDP total capital investment cost is projected to be BDT 2,978 billion ($37 billion) (GED 2018). This scale of investment is not large, considering Bangladesh growth achievements and the pressing needs of its obsolete infrastructure and low productivity in the face of progressively worsening effects of climate changes. Presently the government spends about 0.8 percent of GDP on programs that for content and targets can be assimilated to BDP directions, but it is estimated that additional resources for at least an additional 1 percent would be needed.

In the model experiments, we have tried to reproduce in stylized form the main characteristics of key BDP projects aimed at some of the main achievement targets outlined in table 7.7. For this purpose, we have implemented a main program package, focusing on improvement of water supply and management.

Table 7.7 Main national strategies of Bangladesh Development Plan

Strategy FR 1: Protect Economic Strongholds and Critical Infrastructure
• Sub-strategy FR 1.1: Protection by development and improvements of embankments, barriers and water control structures (including ring dikes) for economic priority zones and major urban centers.
• Sub-strategy FR 1.2: Construct buildings that are adaptive and resilient to flood-storm-surge.
• Sub-strategy FR 1.3: Adopt spatial planning and flood hazard zoning based on intensity of flood.
• Sub-strategy FR 1.4: Improve Flood Early Warning System services (both for basins and hotspots); and
• Sub-strategy FR 1.5: Improvement of Drainage.
Strategy FW 1: Ensure Water Availability by Balancing Supply and Demand for Sustainable and Inclusive Growth
The freshwater strategy is aimed to ensure water availability by balancing supply and demand for sustainable and inclusive growth. The cross-boundary issues become important here. Sub-strategies include:
• Sub-strategy FW 1.1: Ensure optimum water resource management in the country following basin wide management along with construction of necessary embankments.
• Sub-strategy FW 1.2: New irrigation schemes for the major rivers of the country.
• Sub-strategy FW 1.3: Excavate of local water reservoirs (canals, ponds and baors) for restoration of water and rainwater harvesting.
• Sub-strategy FW 1.4: Construct Rubber dam preceded by appropriate feasibility study.
• Sub-strategy FW 1.5: Enhance freshwater flows in urban and regional rivers.
• Sub-strategy FW 1.6: Restore natural reservoir and water bodies along with their biodiversity conservation.
• Sub-strategy FW 1.7: Preserve ground water level by restriction on excessive extraction of ground water; and
• Sub-strategy FW 1.8: Increase the freshwater flow in urban and rural rivers and control of river pollution.
Strategy FW 2: Maintaining Water Quality for Health, Livelihoods and Ecosystems
This strategy is based on the second objective "water quality" of the freshwater strategy. Water quality is a growing concern for the country, with many rivers and wetlands at serious environmental risk. To ensure healthy lives, livelihood and ecosystem of Bangladesh, the quality of water needs to maintain according to rules and regulation. Sub-strategy includes:
• Sub-strategy FW 2.1: Appropriate waste management and reduction of pollution in urban and rural areas.
• Sub-strategy FW 2.2: Monitor and control of pollution; and
• Sub-strategy FW 2.3: Conduct action research for improved ecosystem services.

Source: GED 2018.

Box 7.2 Delta plan strategy and projects' CGE Simulations

The CGE model simulates the BDP investment plan in the projects' construction phase through the implementation of an investment shock that yields direct, and indirect demand led effects on the Bangladesh economy. In the projects' operational phase, the plan is analyzed as an activity added to the national economy as a more sustainable form of production which can be endogenously expanded as an alternative to traditional production technology and value chain composition.

The water program analyzed is consistent with BDP investment priorities and include flood protection, control and drainage, river erosion control, river management, urban and rural water supply and waste management and institutional capacity building. Estimated investment costs are around $17.3 billion. The investment components are water infrastructure, such as installation of piped water supply system both in urban and rural areas, water treatment facilities, storage, transmission, and distribution networks, including house connections. An important component is an expanded and upgraded sanitation system, with comprehensive investments for sanitation septage, drainage and management of grey water and storm water flooding. Other investments include public toilet construction and management cleaning support from informal workers with equipment and training for fecal sludge management. Institutional capacity building will also be pursued by investing in institutional capacity on water sanitation and services through IT and accounting, water quality monitoring systems, contract management capacities, gender action plans and financial support.

In the operational phase, the physical and human capital capacity realized in the projects' construction phase is expected to bring several benefits. These are both estimated ex ante and endogenously quantified by the model. They include reduction of mortality and morbidity costs, of agricultural and nonagricultural water pollution, GDP increases and income and price effects.

Source: World Bank.

7.5.2 Program simulation

Tables 7.8 and 7.9 summarize the basic structure and Figures 7.5–7.8 report the economic results of the water supply and management (WSM) program hypothesized for the 13 years covered by the CGE simulations. Estimated total economic benefits include both those generated by the employment expansion caused by the construction works and the longer-term increases in incomes and reduced externalities produced by the adoption of the program on the part of farmers and market operators in all regions of the country. Net benefits appear to be large both in terms of GDP gains and reduction of harmful externalities (figure 7.5 and 7.6).

The results also suggest that the WSM program would have the largest impact on skilled labor incomes and returns to capital (Figure 7.7), thus engendering further investment in human and nonhuman capital, with positive income distribution effects, inverting the deterioration envisaged from the base year and bringing the total household income share of the poor from 10.6 percent to 11.3 percent (Figure 7.6).

Table 7.8 Water Program target cash flow (direct costs) | *$, millions*

	Total (2021–27)	Present value
Investment costs		
Construction	2,362.50	1,998.55
Services	590.63	499.64
Water distribution	1,771.88	1,498.92
Health	7,087.50	5,995.66
Total investment costs	**11,812.50**	**9,992.77**
O&M costs		
Construction	1,102.50	779.52
Services	275.63	194.88
Water distribution	826.88	584.64
Health	3,307.50	2,338.55
Total O&M costs	**5,512.50**	**3,897.59**

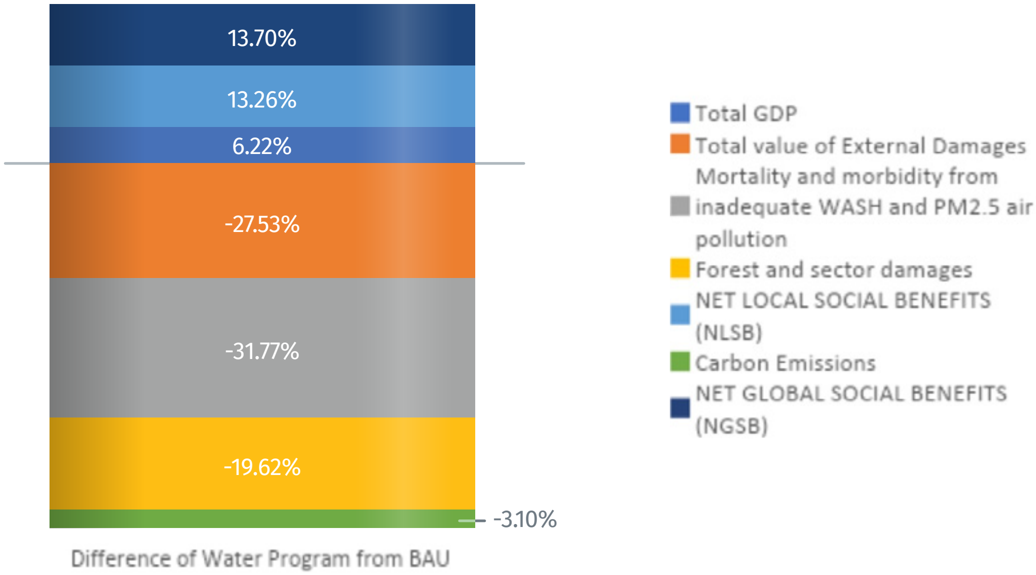
Source: World Bank.

Table 7.9 Water Program revenue target cash flow (financial revenues) | *$, millions*

Revenues	Total (2021–40)	Present Value
Reduction of mortality and morbidity costs	9,647	6,964
Reduction of agricultural water pollution	1,281	925
Reduction of non-agricultural water pollution	4,595	3,317
Reduction of CO_2 emissions	4,339	3,132
Increasing GDP due to avoided working day losses	44,369	32,030
Total benefits	**64,231**	**46,368**

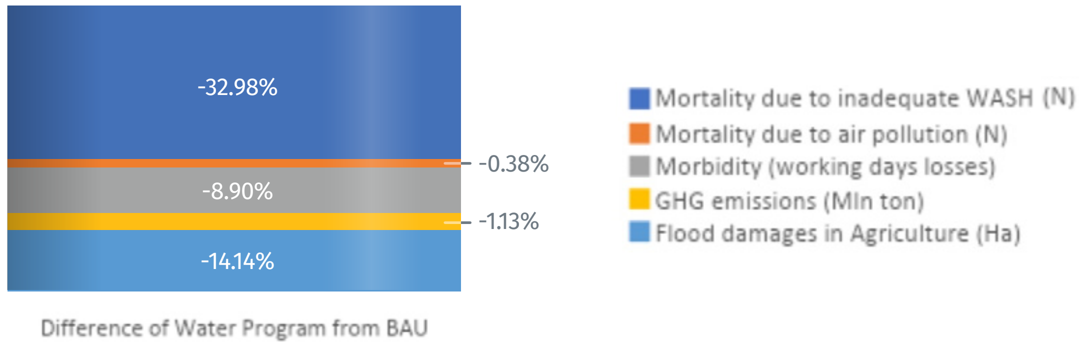
Source: World Bank.

Figure 7.6 Economic impact of the water program (higher or lower growth than the BAU from the baseline)



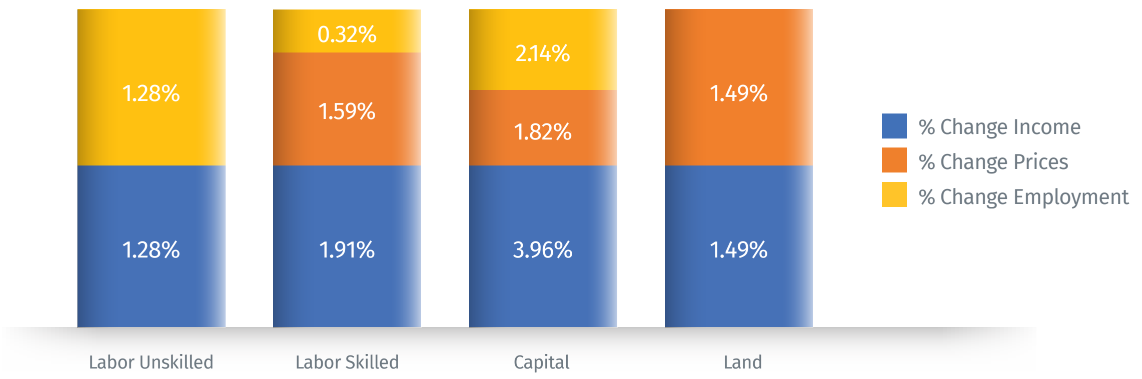
Source: World Bank.

Figure 7.7 Impact of the Water Program on externalities (lower growth than the BAU from the baseline)



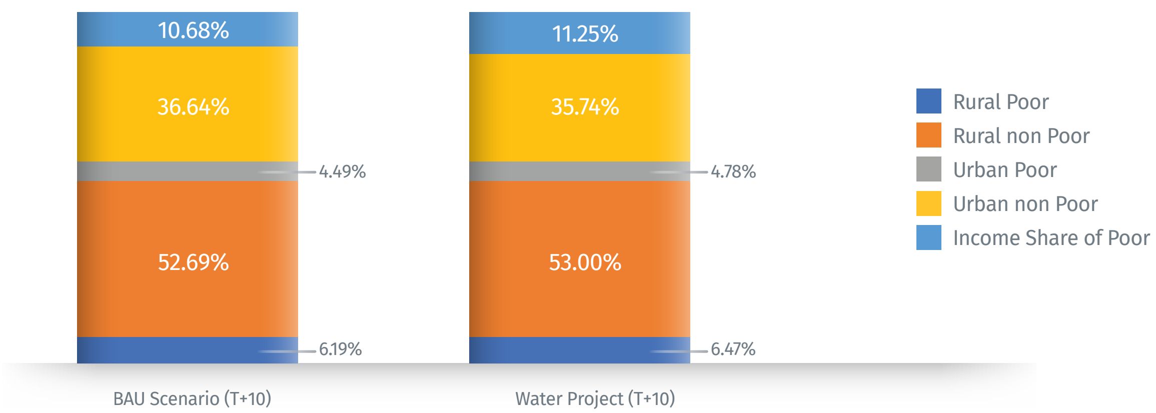
Source: World Bank.

Figure 7.8 Impact on employment of the Water Program (higher growth than the BAU from the baseline)



Source: World Bank.

Figure 7.9 Income distribution impact of Water Program: Percent of total income by household groups



Source: World Bank.

7.5.3 Summary of above findings

The main results obtained from the water program experiments can be summarized as follows. The water project simulated by the model embodies several features of the ambitious program set up in the BDP. Consistent with BDP investment priorities, the project includes flood protection, control and drainage, river erosion control, river management, urban and rural water supply and waste management and institutional capacity building.

Even though the model experiments do not cover the whole-time span of the program (up to 2040), estimated total economic benefits include both those generated by the employment expansion caused by the construction works. They also include, limitedly to the ten years considered, the increases in incomes and reduced externalities produced by the adoption of the program on the part of farmers and market operators in all regions of the country. The model experiments also aim to validate the ex-ante benefit and cost estimates by endogenizing the rate of adoption of the input package contained in the projects' cash flow.

The CGE results for the endogenously generated employment, production, income, and price variables, for both the construction and the operational phases, appear to be in line with ex ante cash flow estimates and substantial both in terms of GDP gains and reduction of harmful externalities. The model simulations also indicate that the program would have the largest impact on skilled labor incomes and returns to capital, thus engendering further investment in human and nonhuman capital. The income distribution impact of the program would be significant, with a total income share of the poor raising from 10.7 percent to 11.3 percent. More generally, the model suggests that the water management components of the stylized investment program examined could be successful in terms of adoption rates and diffusion as alternative technologies for agricultural production.

7.6 Conclusions

This chapter has analyzed several policy measures for Bangladesh development strategy with the help of a CGE Model (Bangladesh Bioeconomy CGE 101). The policies examined include the removal of energy subsidies, several carbon market measures aimed at setting appropriate carbon prices and a water supply and management development program. The results of the analysis can be summarized under the following main points.

The analysis of the subsidy removal and the carbon-tax policies reveal different effects. The subsidies distort relative prices of energy and thus their removal increases economic efficiency by correcting a misalignment between market prices and private opportunity costs (directly of electricity and gas and indirectly of all other prices in the economy). In doing so they also tend to reduce the misalignment between private and social opportunity costs for carbon, but this is only a secondary effect, largely dominated by the impact on electricity and gas prices. The carbon tax, as well as other carbon pricing instruments, on their part, tend to correct the misalignment between the private and the social opportunity cost of carbon emissions across the whole economy. Thus, a carbon tax subsumes the effect of removing the subsidy and the simulation results suggest that it may be combined by a gradual removing of the subsidies, thus making its effects more incisive and more politically acceptable in the short run.

The model's results suggest that removing the current energy subsidies could be a good first step for a fiscal-policy intervention. This would have beneficial effects on both economic efficiency and environmental protection. The policy would also be beneficial for equity if the government savings were redistributed to the poor. While this redistribution would reduce the environmental benefits of the policy, the overall social benefits would still outweigh the costs. The policy would have positive effects on the environment and human health compared to the business-as-usual scenario. However, it is important to note that the environmental effects of the policy could be even more positive if we considered the impact of the transfer on the use of less polluting fuels by the poor. The transfer could help the poor to switch to cleaner fuels, such as solar energy or natural gas, which would reduce their emissions and improve air quality.

Setting the stage for efficient carbon markets also appears to be a feasible policy for Bangladesh with several beneficial effects, especially if combined with suitable redistribution policies to poorer households. Applying a carbon tax to production at a rate proportional to carbon emissions would have negative results on GDP at market prices, but this would be almost completely countervailed by the values of externality reductions. Moreover, social gains from a more efficient resource allocation and reduction of externalities turn out to be large and positive if evaluated at shadow prices. A carbon tax combined with redistribution of its proceeds to households below the poverty line displays net social benefits at shadow prices (but not at market prices) for all values of the tax. It also yields the best impact on income distribution and the conditions of the poor, even though this implies a lower effect on externality reduction. A carbon tax combined with a cap-and-trade system appears to be neutral for income distribution, but successful from an efficiency standpoint since it both increases GDP and reduces externalities. As in the redistribution case, however, by allowing the expansion of larger polluters, carbon trading has the side effect of lowering the performance of the tax in reducing the negative externalities. In sum, while a straight carbon tax would yield net benefits on purely efficiency grounds, a combination of a moderate tax with a program of lump sum transfer of its proceeds to the poor would achieve the best results in terms of income distribution and reduced external damages.

Testing with the CGE simulations an ambitious water supply and management program designed in accordance with the BDP priorities, shows the potential benefits of a development strategy aimed at increasing productivity, improving water management, and protecting the environment. The CGE experiments focused on a water supply and management program that was simulated in detail to analyze costs and benefits for the country as well as for a range of its stakeholders. The experiments were designed to reproduce some of the main features of a large program aimed at boosting yields, protect the environment, and improve water management. The results suggest that this project typology could be highly successful in combining productive and environmental benefits and would be usefully complemented by the fiscal policies analyzed in the first two parts of the paper.

The economic modeling exercise carried out to assess investment in water management suggests thus that this program could be highly beneficial. Unlike the other measures considered, it would mobilize local labor and other unemployed resources and it would not need to sacrifice value added to achieve sizable gains in shifting land and capital usage to reduce negative externalities. However, this type of investment is itself only sustainable if government resource commitments are accompanied and followed by concurring private behavior. Convincing people to abandon traditional land and water management practices, and to switch from the present modes of production to more sustainable ones, requires both persuasive power and sufficient incentives. Combined with an effective information and extension program, public investment should be complemented by policies aimed to nudge local agriculturists toward more sustainable land and water use practices, by not only providing feasible alternatives to the present form of agriculture and repairing some of its damages, but by also immediately increasing employment and economic activity in rural areas.

The results presented are based on a large and detailed economic model and can be interpreted as indicating that the policy measures examined may be reasonably effective in generating benefits (reduction of externalities), increase GDP and improve the condition of the poor. At the same time, taken individually, none of the fiscal and investment policy measures alone is likely to be able to sustainably deliver the desirable increases in incomes and reduced externalities desired. Obstacles include low efficiency, possible unintended reactions to subsidy removal and tax levying, enforcement costs and noncompliance. In the case of the water program, while the model predicts high rates of adoption of improved practices and technologies, difficulties may arise from lack of experience, risk aversion and financing bottlenecks.

Discontinuing energy subsidies, imposing carbon taxes, extending carbon credits, and other finance and fiscal instruments can usefully support sustainable agriculture and water management programs. The model results suggest that BDP investment programs for agriculture and water should be carried out to the full extent envisioned by government planners. To enhance their effectiveness, however, they should be combined with conservation incentives (such as carbon taxes) and/or supported by equivalent subsidies (payments for ecological services), as well as by targeted transfers to the poor. By aligning private incentives to social goals, these measures could ensure that the infrastructure financed be put to appropriate use and not ignored or even jeopardized by direct or indirect private actions.

Finally, more research and analysis would be necessary to examine in greater detail the policies that would be likely to be more successful in the pursuit of a national strategy of sustainable and inclusive growth. In its present and further enhanced forms, the CGE model could support a comprehensive review of the Bangladesh investment plans to analyze and identify effective policy measures and their likely impact on a plurality of stakeholders.

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Endnotes

63 The experiments are all performed under the assumption of a Keynesian closure—that is, the hypothesis of structural unemployment of part of the labor force and corresponding wage rigidity.

64 This literature review included the following studies: Acharya and Sadath (2017); Amin and Renstro (2018); Bresinger et al. (2019); Dartanto (2013); Elshennawy (2014); Glomm and Jung (2015); Griffin et al. (2016); Hong et al. (2013); Jiang and Tan (2013); Jiang et al. (2015); Shaffitzel et al. (2020); Solymani and Kari (2014); Timilsina and Pargal (2020); Timilsina et al. (2018); and Yusuf and Resosudarmo (2008). A recent study by Timilsina and Pargal (2020) for Bangladesh applied a CGE model to study the impact of the removal of price subsidies on electricity and natural gas. They considered four alternatives of funds reallocation with resulting positive impacts across the country's economy. Their simulations included a 33 percent reduction of the electricity subsidized price and an increase in the domestic retail natural gas price to align it with the international price, bringing the weighted average price to 8.51 $/GJ. These price changes were combined with four redistribution schemes: (a) an excise tax reduction, where the savings were used to cut all other excise taxes on goods and services; (b) a cut in income taxes, where savings were used to reduce the income taxes on households and firms; (c) a lump-sum transfer, where savings were used to increase households' disposable income; and (d) an investment program, where savings were used to invest directly in the economy to increase capital stock. Without redistribution, they found an increase in price of energy intensive goods and services and, consequently, negative effects on producers and consumers. With redistribution, the gross output and demand for all the four schemes of redistribution improved. The highest GDP increase occurred with the investment program, while the lowest increase was under the lump-sum scheme.

65 Lump-sum payments may be based on government transfer to the poor (G2P) that exploit existing financial networks of pension and relief payments and public work guaranteed schemes to transfer cash income by incurring in minimal efficiency costs. These programs include direct income supplements, as in China for people below the poverty line (Bankable Frontier Associates 2006, 2008, 2009), or workfare programs that create jobs to alleviate unemployment and help smooth income (del Ninno, Subbarao, and Milazzo 2009). For example, India's National Rural Employment Guarantee Scheme made payments to 45 million poor people working on rural construction programs during fiscal year 2008–2009 (Ministry of Rural Development 2009). Since 2008, Bangladesh has also launched a program guaranteeing 100 days of employment for the poor each year (Reuters, September 15, 2008). More recently (2020), G2Ps have been advocated as an effective policy measure to contain the devasting social effects of the COVID-19 pandemic. For example, a paper of the United Nations Development Programme (UNDP), entitled "Temporary Basic Income: Protecting Poor and Vulnerable People in Developing Countries," suggests that giving cash to the poorest 2.8 billion people in 132 developing countries would help contain the spread of the infection and provide substantial relief to the poor.

66 Following Weitzman (1976), GDP can be considered equivalent to a measure of efficiency if valued at shadow prices.

67 In the no-distribution scenario, while government expenditure is endogenous, the reduction of the deficit is not necessarily a benefit if the growth rate of the economy is above the interest rate on public debt. However, debt sustainability and future income trade-offs would depend on how exogenous variables evolve as well as on the efficiency of government expenditure.

68 Externalities include damages due to loss of forest and loss of output of other sectors (agriculture and industry) due to flooding.

69 The technical appendix presents sector details of the simulations.

70 Bangladesh CO2 Emissions - Worldometer (worldometers.info)

71 While institutional arrangements may be different (in terms of sectors, ways to implement the prices in different circumstances, and penalty levels and enforcement costs), carbon-price instruments are ultimately all taxes from an economic point of view. For example, a tax on fuels is implicitly a tax on emissions, while a tax on emissions has an equivalent tax impact on fuel. An ETS is a tax with its rate conditional to the trading and emission permits acquired at the government's minimum auction price. If these are zero, as it was recently in California, an ETS is just a tax.

72 As for subsidy removal, the long-run impact of higher income revenues could be positive both because of higher financial sustainability of government debt and because of a lower burden of taxation on future generations.

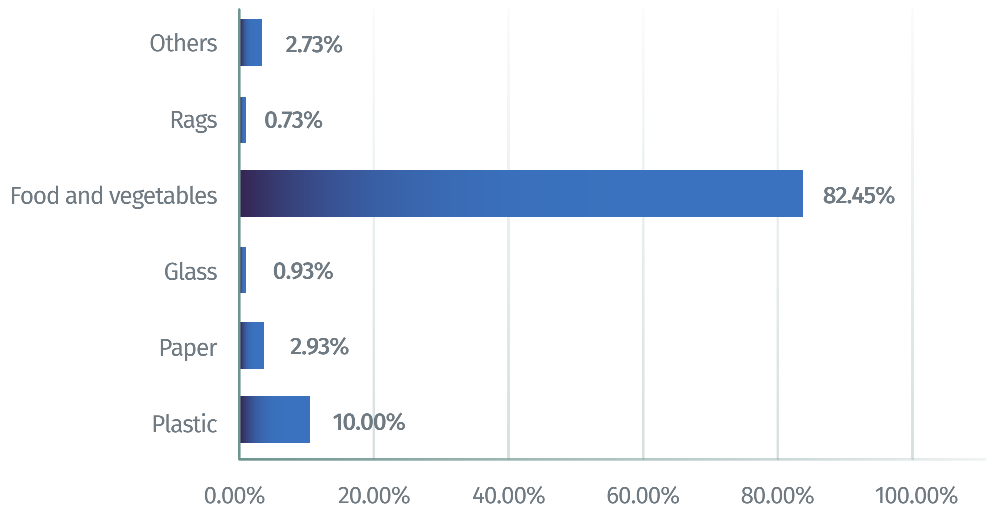
CHAPTER 8. ADDRESSING PLASTIC POLLUTION IN BANGLADESH THROUGH INTEGRATED SOLID WASTE MANAGEMENT

8.1 Introduction

Waste management is a growing issue given Bangladesh's 0.28 kilograms of waste per capita per day. This is far lower than the global (0.74 kilograms/capita/day) and regional averages (0.52 kilograms/capita/day) (Kaza et al. 2018). However, a large population and inadequate waste management mean high waste accumulation in the environment. Moreover, Bangladesh's waste production is expected to double by 2050, putting further pressure on waste management and the environment (Geyer, Jambeck, and Law 2017). Although plastic represents around 10 percent of the solid waste composition (World Bank 2021b), in Bangladesh, it poses a serious threat to the environment.

Plastic waste is burned and openly dumped together with other solid waste streams. This leads to the enormous generation of mismanaged plastic waste and a mounting pollution crisis: The waste accumulates on land, the banks and beds of waterways and clogging drains, polluting ecological systems. This often leads to increased flooding and river pollution and creates health risks such as vector-borne diseases and respiratory illnesses from waste burning. Since rivers discharge into the sea, plastic pollution in waterways is directly linked to marine pollution. Recycling of plastics in Bangladesh is mostly informal and unregulated, posing challenges and also opportunities to provide the base for a strong and inclusive circular economy. Technical and financial support to improve the reliability, scale, structure, and linkages with regional and global markets needs to be in place to further develop this sector. However, proper disposal and integrated waste management remain the key solution to address the plastic pollution problem. This requires investment and institutional capacity building supported by a strong policy framework. (See figure 8.1 and box 8.1.)

Figure 8.1 Waste composition in Dhaka South City Corporation (DSCC), 2020 | *Percent*



Source: Figure reproduced with modifications from World Bank (2021b)
Note: The figure shows the waste composition at the source and the waste composition at disposal (landfilled waste).

This chapter provides an overview of the impacts of pollution and elements of Bangladesh's current plastic waste management system. The chapter also outlines the key policy recommendations that complement the Multisectoral Action Plan for Sustainable Plastic Management in Bangladesh (World Bank 2021b) to support the transition towards circular economy and integrated waste management.

Box 8.1 Plastic waste is labeled as hazardous

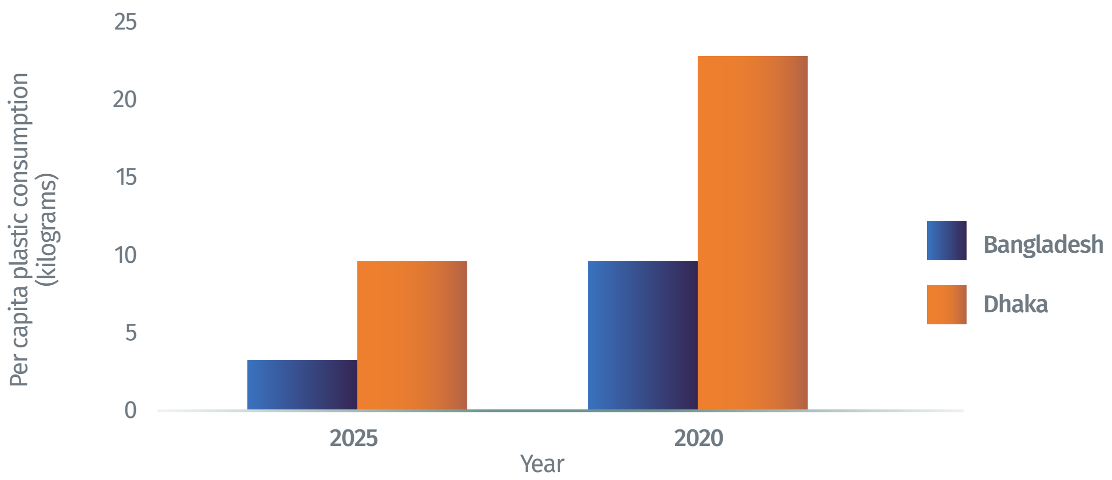
Since 2019, the Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and their Disposal of the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal considers some types of plastic waste as hazardous. Plastic waste that is destined for recycling in an environmentally sound manner and almost free from contamination is presumed not to be hazardous. Thus, any mixtures of plastic wastes consisting of polyethylene (PE), polypropylene (PP), or polyethylene terephthalate (PET) that is not disposed in an environmentally sound manner is considered hazardous under the Basel Convention.

Source: UNEP 2019.

8.2 Plastic waste consumption and disposal in Bangladesh

Plastics are an integral and ubiquitous part of economic activity, waste generation, and modern life across Bangladesh. The qualities that make plastic useful—lightness, durability, strength, versatility, and low production costs—have resulted in fast-growing demand (Worm et al. 2017). With rapid growth and urbanization, Bangladesh's annual per capita national consumption of plastics rose over the past fifteen years from 3.0 kg in 2005 to 9.0 kg in 2020 (figure 8.2) (Enayetullah, Sinha, and Khan 2005; World Bank 2021b). Annual plastic consumption rate in Dhaka, the center of Bangladesh's economic progress and industrialization, is even higher and is estimated to be 22.25 kg per capita.[73]

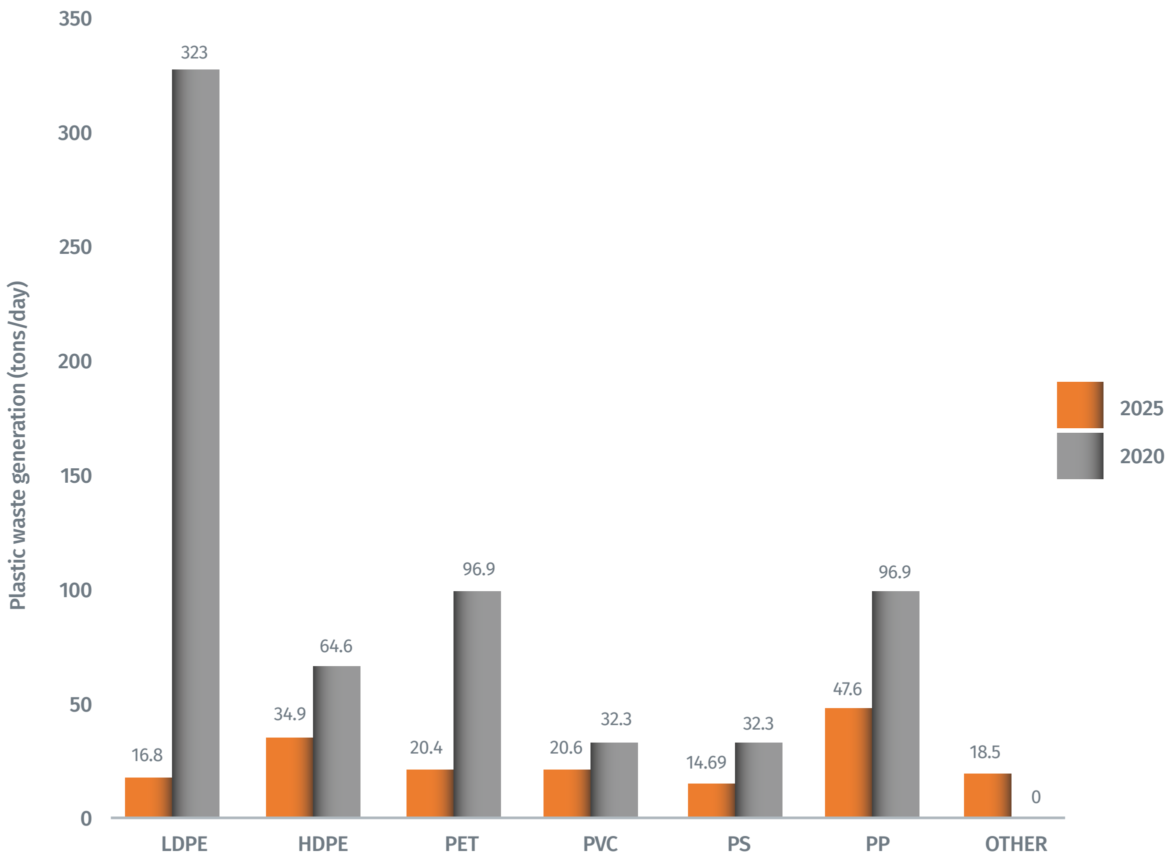
Figure 8.2 Per capita plastic consumption in Dhaka and Bangladesh in 2005, 2014, and 2020



Source: Figure reproduced with modifications from World Bank (2021b).

Households in Bangladesh produce more packaging waste than other types of plastic waste. Households in Dhaka generated *over nineteen times as much* low-density polyethylene (LDPE) (mainly used for packaging) in 2020 (323 tons per day) as they had in 2005 (16.8 tons per day) (World Bank 2021b). Packaging is responsible for 73 percent of plastic waste in Bangladesh (figure 8.3). Consumption of LDPE packaging increased fivefold in 2020 compared to 2005. At the household level, 40.6 percent of LDPE in waste composition comes from single-use shopping bags. The COVID-19 pandemic has increased the consumption of packaging and shopping bags made of LDPE because they were perceived to be safer than reusable options. According to a survey conducted in 2022 to determine plastic-use patterns in communities living near the canals and rivers of Dhaka City, 41 percent of respondents identified plastic bags as their plastic products with maximum use, 23 percent named bottles, and 21 percent used plastic buckets most often (World Bank 2023a). A similar pattern is found in Cox's Bazar (box 8.2).

Figure 8.3 Composition of household plastic waste, 2005 and 2020 | *Tons per day*



Source: Figure reproduced with modifications from World Bank (2021b).
Note: LDPE = low-density polyethylene, HDPE = high-density polyethylene, PET = polyethylene terephthalate, PVC = polyvinyl chloride, PS = polystyrene, and PP = polypropylene.

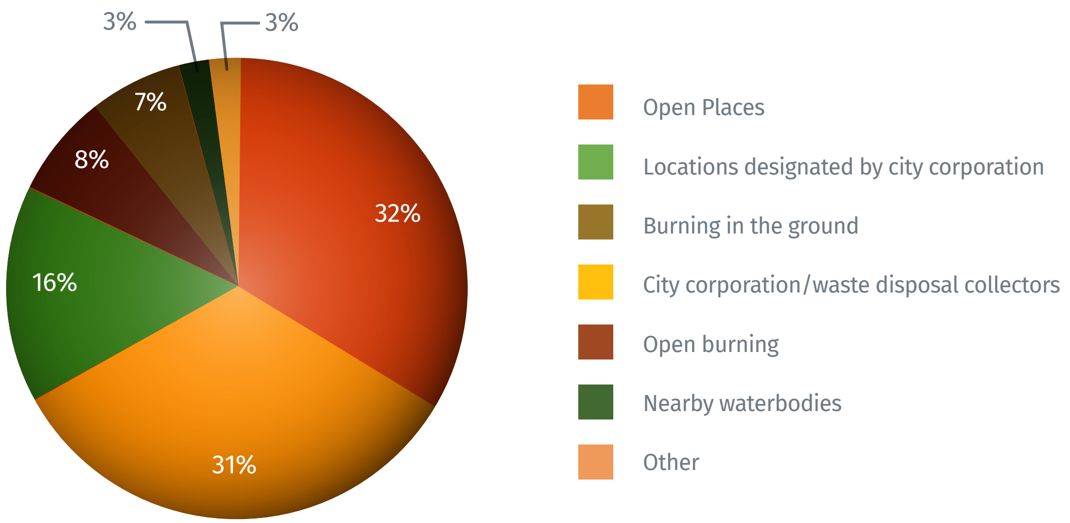
Box 8.2 Plastic consumption and disposal in Cox's Bazar

A qualitative survey and field observations of over 80 stakeholders in Cox's Bazar, including businesses, customers, and government entities, indicated that single-use plastic cups, water bottles, and polyethylene bags were the most frequently used plastic products. The respondents reported using plastic due to its affordability, light weight, and durability. Hotel representatives reported using personal care products and cleaning materials. Those in the food-service business reported using food packaging. Customers used polyethylene bags and single-use food packaging, such as cups and cutlery, as well as personal-care products like soap and toothpaste packaging. The primary waste-disposal methods in Cox's Bazar include open dumping and burying of waste, followed by segregating, littering, burning, and rarely, recycling.

Source: World Bank 2023c.

Most plastic waste generated in Bangladesh is not adequately managed. Of the 977,000 tons of plastic waste generated annually in Bangladesh, almost 70 percent is disposed of along roadsides, riverbanks, open dumpsites, illegally littered, or openly burned (World Bank 2021b). In 2022 in the capital Dhaka, 33 percent of plastic waste was openly dumped, 8 percent openly burned, 7 percent buried in the ground, and 3 percent disposed in nearby waterbodies, such as rivers, canals, drains, and ponds. Only 31 percent of plastic waste was managed by city corporations and other waste collectors (figure 8.4) (World Bank 2023a). Rural areas have lower collection coverage, estimated to be half that of an aggregate urban rate (Kaza et al. 2018).

Figure 8.4 Plastic waste disposal methods in communities living near rivers and canals around Dhaka City



Source: World Bank 2023a.

Approximately 47,000 tons of plastic pollution was identified in terrestrial and riverine environments at 43 sites around Dhaka City (figure O.1 in appendix O). Plastic items identified include personal-care products, building materials, automobile components, medical equipment, food packaging, marine sourced-goods, furniture, and other items (World Bank 2023a).

8.3 Plastic pollution through abandoned, lost, or otherwise discarded fishing gear (ALDFG)

The fishery sector is highly important in Bangladesh, with about 1.2 million people employed through inland fishing and 300,000 employed in marine fishing. Approximately 40,774 vessels spend approximately 201 days/vessel/year fishing with 360 kilograms of gear on average per vessel. The types of fishing gear commonly used in Bangladesh include demersal or bottom trawling fishing gear, fish aggregating devices, gillnets, handlines, longlines, pole and line, purse seines, set bags, and surrounding nets. As gear becomes compromised, it may become abandoned, lost, or otherwise discarded (ALDFG). A new pilot program has begun to promote gender-equitable ALDFG recycling programs in Bangladesh's coastal communities (box 8.3).

Bangladesh produced over 6,000 tons of ALDGF in 2021 (table 8.1) (World Bank 2023b). Although not apparent from the numbers, many fishers in Bangladesh are in small commercial and artisanal fisheries that use monofilament gillnets. Monofilament gillnets snag and entangle easily. Thus, this gear is frequently discarded or otherwise disposed of. Reasons for ALDFG events vary and include theft (31 percent), oceanic/meteorological/weather conditions (26 percent), gear conflict/shipping interactions (6 percent), snagging (4 percent), and other/unspecified (31 percent) (World Bank 2023b).

Table 8.1 Number, quantity (by weight), and value of ALDGF in Bangladesh in 2021

Measure	Amount
Number of ALDFG events per vessel	6
Total number of ALDFG events	237,018
Quantity of ALDFG from all vessels (tons)	6,085
Fraction of ALDFG compared to total gear onboard all vessels (%)	41%
Cost of replacing ALDFG from all vessels ($)	72,383,573
Value of ALDFG compared to total value of gear onboard all vessels (%)	54%

Source: World Bank 2023b.

Box 8.3 Piloting gender equitable value chains for recycling fishing nets in coastal communities in Bangladesh

Obsolete fishing nets in Bangladesh are discarded into the river and sea, buried in the ground, thrown into a pond or ditch, or used as an alternative to fuelwood. A study conducted in 2022 identified a discarded net density near the seashore and in riverbanks of 2.48 items/m2 in Charfesson and 0.91 items/m2 in Cox's Bazar. All types of discarded nets consisted of Nylon-6, which indicates that there are good prospects for establishing net recycling into yarn in coastal communities in Bangladesh. International recycling markets explored focus on recycling the nets into yarn. The global nylon market is growing and expected to reach $30 billion by 2026 with a compound annual growth rate of 3.3 percent.

To reduce the amount of ALDFG ending up in the environment, opportunities to create new, gender-equitable fishing-net recycling in Bangladesh are being explored in the international and local markets. The current fishing sector and local repair/repurposing sector are primarily run by men so new recycling opportunities could also pose opportunities for furthering gender equity.

Source: World Bank 2023d.

8.4 Impacts of plastic pollution

Plastic waste and pollution have far-reaching economic, ecological, and health implications (figure 8.5). Single-use plastic packaging (especially polyethylene bags) increases waste accumulation and blockages in drainage systems, impeding the unobstructed flow of rainwater. In the last few decades, especially 9during monsoons, plastic waste blocking drainage systems has become a "risk multiplier" for flooding (McVeigh 2023). Local authorities incur significant costs in conducting cleanup operations. For example, the Dhaka Water Supply and Sewerage Authority (Dhaka WASA), which is responsible for managing sewers in Dhaka, spent $23 million in 2018 to clean up city sewers, including the emergency excavation of 25 kilometers of canals and clearing 290 kilometers of drains (Molla 2018).

Several studies indicate strong linkages between plastic trash and mosquito vector-borne diseases including dengue, malaria, and chikungunya infections, especially in countries and communities where trash collection, disposal, and management frameworks are in their nascent stage (Khan et al. 2023; Maquart et al. 2022). A study conducted in Kolkata shows that household wastes in urban and rural areas—mostly plastic waste—create favorable breeding environments and habitats for mosquitoes[74] and are reservoirs for pathogens (Banerjee et al. 2015; Maquart et al. 2022). Between 2018 to 2023, the number of reported cases of dengue infection increased by nearly sevenfold, and mortality grew by 80.77 percent (WHO 2023). This has economic implications: Studies show that the societal cost[75] of treating one dengue episode in Bangladesh, including household and provider costs, was BDT 39,893 ($479) (Sarkar 2021).

Plastic waste retained by aquatic vegetation and hydro-morphological processes in river and canal beds affects navigability and impedes dredging operations (Chowdhury et al. 2020). Since the inception of the dredging activities in the Karnaphuli River between 2018 and 2021, the amount of waste in the river increased from 42 lakh to 51 lakh per cubic meter, of which the layer of plastic and polythene ranged between two to 10 meters (Ali 2021; Dey 2020). Consequently, the project's cost increased from BDT 2,580 million to BDT 3,210 million in 2021 (Ali 2021; Dey 2021).

The Bangladesh Inland Water Transport Authority noted a similar situation in Barisal where layers of plastic waste stalled dredging operations, which may lead to reduced navigability (Ghosh 2020; Parker 2023). Open dumping of waste occupies valuable agricultural land, while finding new sites for waste treatment and disposal facilities becomes increasingly difficult in a land-scarce country like Bangladesh. Scattered dumping of waste also drives the market and real estate values downward and negatively affects tourism and local economic development (World Bank 2021).

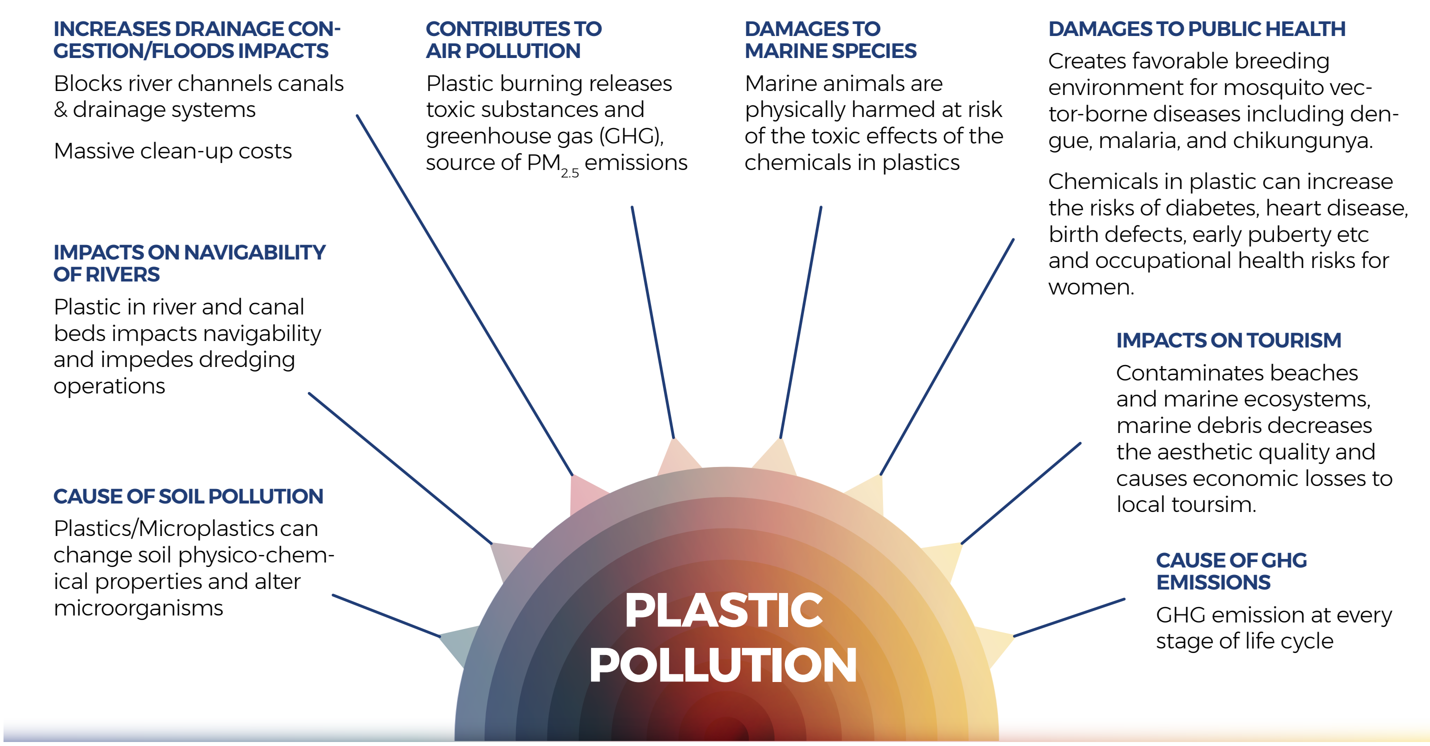
Plastic pollution threatens Bangladesh's water quality and food safety by generating microplastics, adsorbing other pollutants, and leaching plastic additives. Microplastics[76] are plastics less than 5 millimeters in size, and nano-plastics are less than 1 micron in size. Microplastics also contain chemical additives that can leach into water and soil (Groh et al. 2019; Hermabessiere et al. 2017; Li et al. 2016; Wiesinger et al. 2021). Furthermore, microplastics accumulate other environmental pollutants, such as heavy metals and persistent organic pollutants (Rochman et al. 2013b; 2014), that can be transferred to fish and result in physiological stress (Rochman et al. 2013c). Aquatic animals routinely consume microplastics, which can threaten animal health and food safety.

Microplastics are widespread pollutants that are found in ecosystems and wildlife in Bangladesh. Analyses of different species of fish collected from the Bay of Bengal (Khan and Setu 2022) and the rivers around Dhaka (World Bank 2023a) show the presence of microplastics in aquatic animals inhabiting the riverine ecosystems as well as shallow coastal water, nearshore, and offshore areas (Hossain et al. 2019). Brown and Tiger shrimp from the Northern Bay of Bengal have also been noted to contain microplastics (Islam et al. 2022).

About 35 percent of the commonly consumed fish rui or rohu (*Labeo rohita*) and 2 percent of sharputi (*Puntius sarana*) had microbeads present in the gut (reviewed in Chowdhury et al. 2021). Furthermore, 100 percent of the 35 commercially-valuable Hilsa shad (*Tenualosa ilisha*) sampled from the Meghna River estuary in the Bay of Bengal had microplastics in the gastrointestinal tract. Hilsa had a range of 7 to 51 particles per fish—on average 19 microplastics (Siddique et al. 2022). For dried fish, a similar story unfolds. These findings are pertinent given that fish consumption is high in Bangladesh.

Microplastic pollution concentrations vary depending on the season. A detailed study conducted in 2022 to quantify microplastics in the surface waters and sediments of rivers and canals around Dhaka City highlighted aquatic microplastic pollution concentrations varying across time and geographies. In September, October, and November 2022, 51 samples total, each consisting of 200 liters of water, were analyzed from four rivers (Buriganga, Balu, Turag, and Dhaleshwari) around Dhaka City (figure 8.6 and shown in map in appendix L). Samples were collected in river and canal waters using a plankton net with a 300μm mesh size.

Figure 8.5 Impacts of plastic pollution

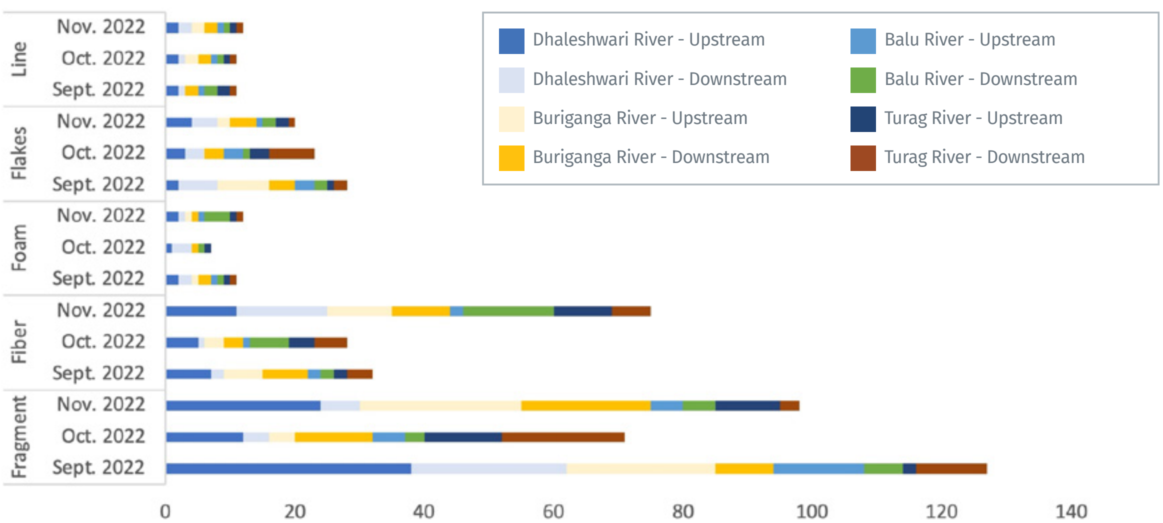


Source: World Bank.

Microplastics flakes and fragments are the dominant shape of microplastics in sediments, while foam and line are infrequently observed. Microplastics undergo deposition into sediments and have been documented in concentrations with over 1,000,000 fragments and flakes per kilogram of sediments from the Buriganga, Balu, Turag, and Dhaleshwari Rivers combined in November and September of 2022 (figure 8.7). In brief, sediments were collected using a grab sample and 1000 mg subsamples were to quantify microplastics. A greater number of microplastics (by count) were observed in sediments as compared to surface waters, likely due to the density of microplastics and increased density due to biofouling over time (Law 2017; De-la-Torre et al. 2023). On average, the greatest number of microplastics were found in September (approximately 250,000 particles), followed by November with 232,000 particles, and lastly October (approximately 147,000 particles). The greatest number of microplastics, 460,700, were observed in sediments upstream of Buriganga River, also in October 2022.

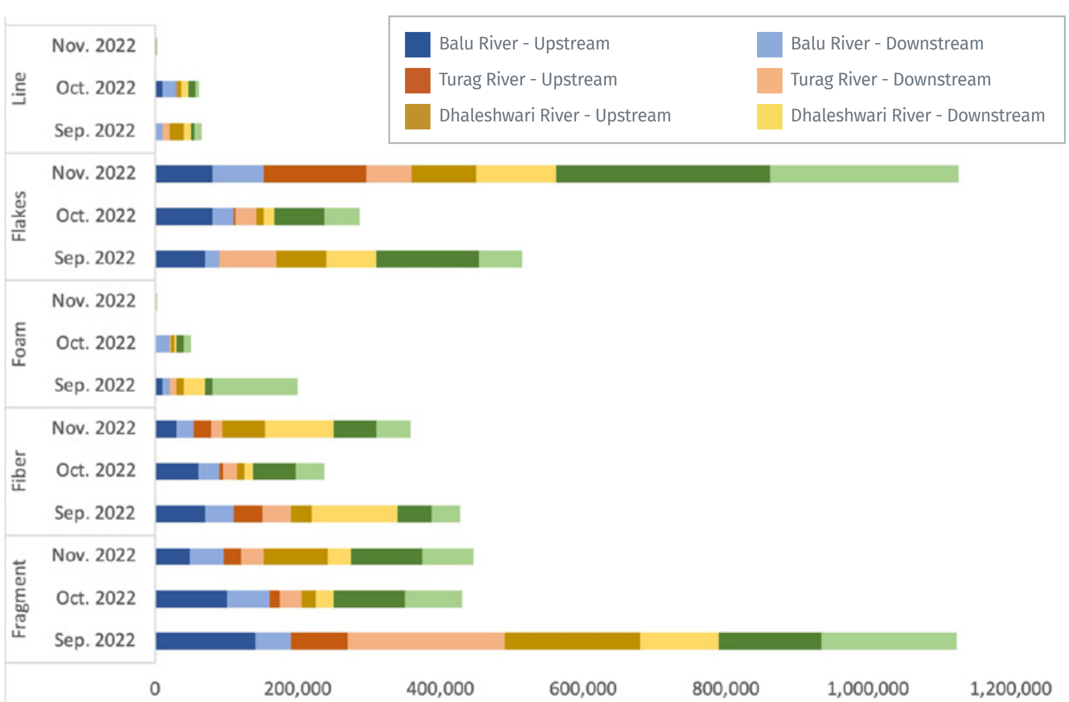
Microplastic fragments, fibers, foams, flakes, and lines have been documented in sediments in rivers and canals in Dhaka City, Bangladesh, and surface waters of the Bay of Bengal, with expected effects on resident animals, microbial communities, and nutrient cycling. Further research is needed to understand the effects of microplastics on sediment ecosystems in Bangladesh; however, we can draw conclusions on laboratory- and mesocosm-based studies. Organisms living in sediments or benthic areas, such as crustaceans, polychaetes, and bivalves, may consume microplastics if they are of the appropriate size, density, and chemical composition (reviewed in Van Cauwenberghe et al. 2015). Microplastics are known to alter sediment microbial communities and can even inhibit or promote nitrogen cycling depending on the type of plastic contaminating the sediment (Seeley et al. 2020).

Figure 8.6 Microplastics found in the surface waters of rivers around Dhaka City | *Particles per liter*



Source: World Bank 2023a.

Figure 8.7 Microplastics found in the sediments of rivers around Dhaka City | *Particles per kilogram of sediments*



Source: World Bank 2023a

Microplastics are also widespread in terrestrial soil systems globally, and further research on microplastic quantification and environmental consequences in Bangladesh is needed (Chowdhury et al. 2021; Hossain et al. 2021). As is the case in the aquatic environment, microplastics in soil can enter the terrestrial food web, potentially resulting in toxicity to plants and animals (Kaur, Singh, and Singh 2022). Microplastics can also change soils' physico-chemical properties, such as porosity, water-holding capacity, bulk density, function, and structure (De Souza Machado et al. 2022; Kaur, Singh, and Singh 2022). The direction of the alteration, such as increasing or decreasing water-holding capacity, varies based on the type of plastic present (De Souza Machado et al. 2022). Furthermore, microplastics alter the microorganisms, such as bacteria and fungi, in the soil, and can inhibit key enzyme activity in nutrient cycling (Kaur, Singh, and Singh 2022).

In addition to affecting aquatic and terrestrial environments, plastic waste can result in significant air pollution, especially when plastic waste is openly burned. Burning plastics releases toxic substances and greenhouse gas (GHG) emissions that contribute to climate change. Humans are exposed to plastic-associated pollutants via many pathways, including inhalation, dermal exposure, and ingestion of contaminated food and water. The open burning of municipal solid waste (including plastic waste) is a major source of $PM_{2.5}$ emissions in Dhaka (see chapters 2 and 4). Plastics and especially additives associated with plastics are known to have many adverse physical and chemical effects on the food web, including inhibition of plant growth, broken nutrient pathways, animals choking, impaired foraging, and chemical uptake in both plants and animals (World Bank 2020).

Box 8.4 Plastic pollution disproportionately impacts women

Women play a key role in all aspects of waste generation and management, from shopping and selection of products to waste picking and employment in waste management. Women in communities without proper waste collection face disproportionate risks in trying to manage waste on their own. Universal waste collection remains challenging, especially since many of the proposed solutions to plastic waste pollution do not incentivize the collection of some of the most hazardous types of plastic. Women tend to burn piles of household waste, which is linked to serious health concerns, such as exposure to the extremely carcinogenic compound dioxin (UNEP 2021). Women are also at risk of gender-based violence (GBV) when trying to find hidden or distant places to dispose of waste (GA Circular 2019). Specific occupational health risks are also present for women (particularly pregnant women) who work with plastic waste or live in communities where plastic waste is illegally disposed of and openly burned. Bisphenol A (BPA) is found in many types of hard plastics and is known as a hormone disruptor. It is known to increase the risks of diabetes, heart disease, birth defects, early puberty, and elevated levels of certain liver enzymes. Plastics marked as BPA-free still often contains some hormone-disrupting chemicals (Stann 2020). Women who have everyday contact with BPA from plastics have an increased risk of miscarriage, polycystic ovarian syndrome (which is known to cause infertility), baldness, and breast cancer (Cariati et al. 2019).

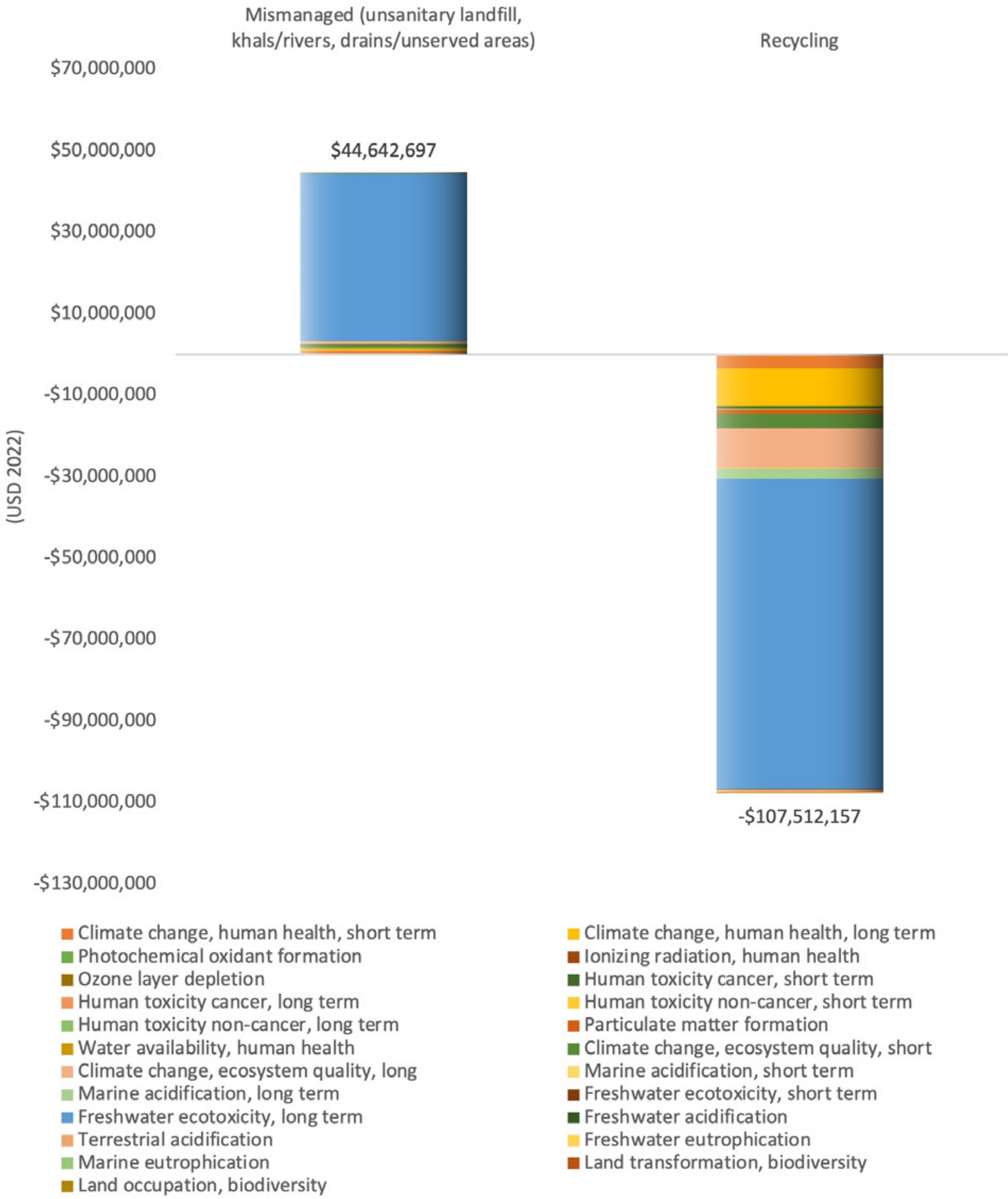
Source: World Bank 2023f.

Beyond significant local impacts, mismanaged plastic waste is a major source of marine litter (Jambeck et al. 2015). Reports suggest that the Bay of Bengal is one of the largest and most important marine ecosystems (Elayaperumal, Hermes, and Brown 2019). The Bay of Bengal receives water from the Ganges-Brahmaputra system and is at extreme risk from plastic pollution (IOC-UNESCO and UNEP 2016). While twenty percent of the estimated marine plastic pollution originates from sea-based activities, the rest leaks from land-based sources. The Ganges-Brahmaputra basin is the second-highest contributor of plastic pollution to the marine environment due to the combination of large tributaries, heavy rainfall, and large populations along their banks (Lebreton et al. 2017).

Environmental impact quantification on the cost of environmental impacts caused by plastic waste in Bangladesh using Life Cycle Assessment (LCA) with focuses on end-of-life system boundaries shows that mismanaged plastic waste (unsanitary landfilling, rivers, and drains) causes as much as $45 million in environmental degradation costs (figure 8.8). The analysis considers baseline study estimates of 2020, which show 30 percent of plastics undergo recycling in Bangladesh (World Bank 2021b); this recycling allows to avoid nearly $108 million of environmental degradation costs (detailed methodology in appendix L2).

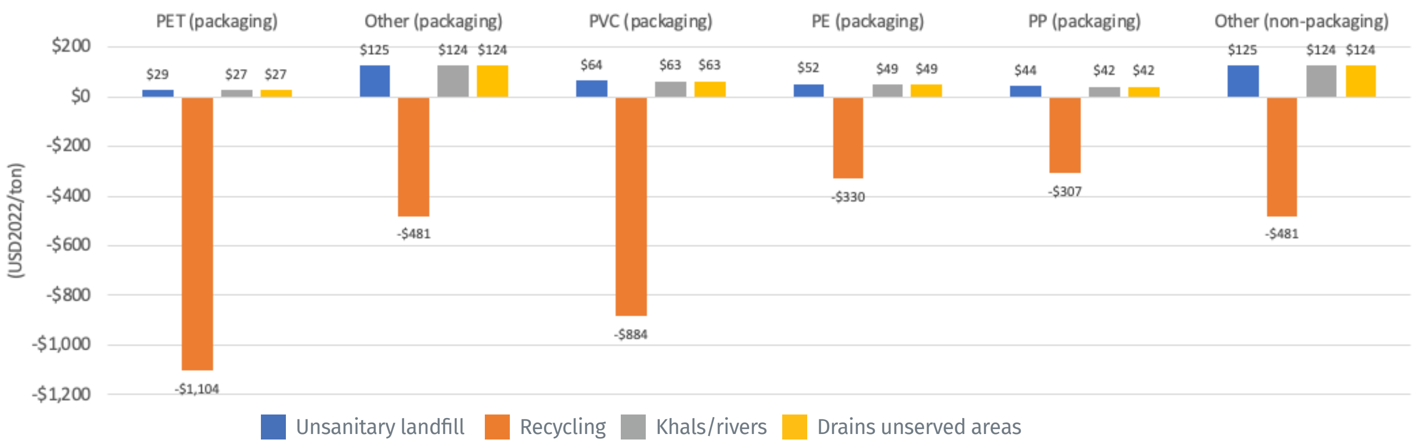
Results show that mismanaged plastic packaging and non-packaging plastics present the greatest costs (99 percent of all plastic waste). Freshwater ecotoxicity presents the greatest fraction of costs (93 percent). Figure 8.9 shows that the recycling of plastics leads to savings of $300 to $1,104 per ton of plastic (figure 8.9).

Figure 8.8 Environmental impact costs of plastics in Bangladesh in one year per impact category using Life Cycle Assessment (LCA) assessment | *In $ (2022 value)*



Source: World Bank.
Note: Five impact categories had extreme impact numbers: Either too low or too high in all four waste-treatment/disposal methods; therefore, these impacts were excluded from the results. They are (a) ionizing radiation, ecosystem quality; (b) water availability, freshwater ecosystems; (c) water availability, terrestrial ecosystems; (d) water availability, human health; and (e) thermally polluted water.

Figure 8.9 Environmental impact costs of plastics in Bangladesh in one year per type of plastic | *In $ (2022 value)*



Source: World Bank.
Note: Five impact categories had extreme impact numbers: Either too low or too high in all four waste-treatment/disposal methods; therefore, these impacts were excluded from the results. They are (a) ionizing radiation, ecosystem quality; (b) water availability, freshwater ecosystems; (c) water availability, terrestrial ecosystems; (d) water availability, human health; and (e) thermally polluted water.

8.5 Governance of waste management

Bangladesh has developed a legal framework for waste management that includes comprehensive laws and regulations. The timeline below (figure 8.10) presents a summary of the policies and regulations most relevant to the plastic supply chain in Bangladesh.

In 2021, the MoEFCC adopted the Solid Waste Management Rules (SWMR) under the 1995 Environment Conservation Act (ECA), setting forth the mandates, principles, and overarching standards for solid waste management in Bangladesh. The SWMR 2021 created the National Solid Waste Management Coordinating Committee (NSWMCC) consisting of high-level representatives from the MoEFCC; line agencies such as the Ministry of Agriculture; Ministry of Finance; Ministry of Housing and Public Works; Ministry of Industries; Ministry of Local Government, Rural Development and Cooperatives; city corporations; academia; NGOs; Federation of Bangladesh Chambers of Commerce and Industry, and plastic manufacturers and importers. The rules require local governments to develop comprehensive SWM plans, covering waste reduction, reuse, and recycling (3R), following a national strategy and guidelines that still need development. The plans must be approved by the National Committee.

Local governments must also submit annual reports to the National Committee. The SWMR 2021 requires separating solid waste at source into three categories: biodegradable, nonbiodegradable, and hazardous solid waste. The rules refer to the extended producer responsibility (EPR) (box 8.5) principle and include standards for composting, refined exudation, solid-waste incineration, landfill requirements, and criteria for converting waste to fuel. The SWMR has appointed a National Coordination Committee (NCC) as the oversight body and authorizes the NCC to frame and update the EPR guidelines.

Box 8.5 Piloting an extended producer responsibility (EPR) scheme for e-waste in Bangladesh

Electronic waste, referred to as e-waste, is frequently hazardous to human and environmental health due to the presence of toxic components such as lead and mercury. E-waste management in Bangladesh is not highly regulated and reliant on the informal sector. Although data specific to Bangladesh are sparse, an estimated 11 percent of e-waste is plastic (Wath, Dutt, and Chakrabarti 2011).

A pilot under the World Bank funded Bangladesh Environmental Sustainability and Transformation Project (BEST) is underway to develop a voluntary extended producer responsibility (EPR) system for e-waste. This program is led by the Department of Environment, Government of Bangladesh, with participation by key stakeholders in Dhaka. The goal of the pilot project is to test the e-waste collection system, recycle the e-waste at the Bangladesh Hi-Tech Park Authority, and use key findings regarding barriers and bottlenecks to inform the development of a scaled-up EPR system. The e-waste products that will be the focus of the pilot project include mobile phones and desktop/laptop computers. The goal of the pilot project is to divert 5 tons of e-waste from the informal collection system to the Bangladesh Hi-Tech Park Authority recycling center using the EPR collection scheme.

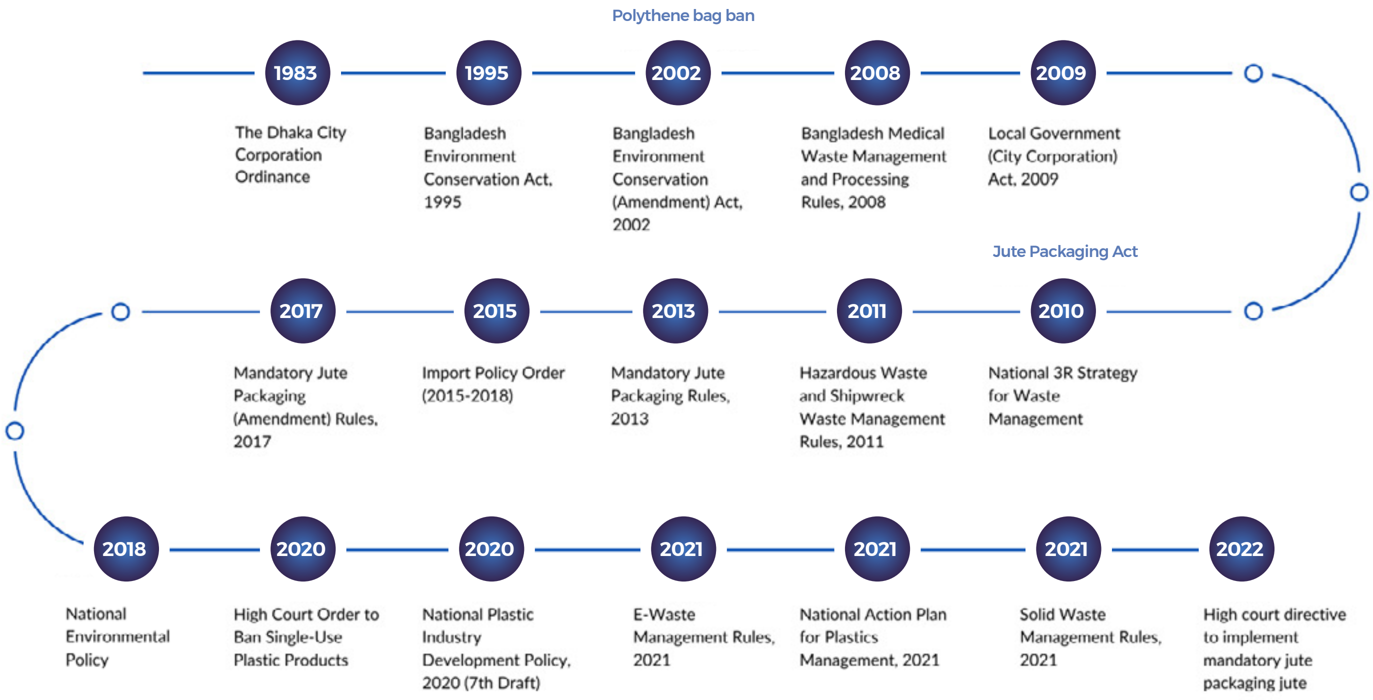
Source: World Bank.

Bangladesh was the world's first country to ban plastic shopping bags through a regulatory order in 2002 under the 1995 Environment Act. There are indications that the ban was initially successful with a decrease in plastic-bag waste during the following years (Ahmed and Gotoh 2005). Unfortunately, this success appears to have been reversed due to a lack of public awareness, limited enforcement of the legislation, and the absence of cost-effective alternatives to carrier bags made of synthetic polymer (Uddin et al. 2019). According to Islam (2019) and others, the government has been successful in implementing the Jute Packaging Act 2010, which mandated the use of jute as a packaging material for essential commodities. In 2020, the Supreme Court of Bangladesh ordered the government to ban the use of single-use plastics (SUPs) in hotels and restaurants in coastal areas within a year to reduce plastic pollution in the Bay of Bengal (Paul 2020).

Also in 2021, the MoEFCC endorsed the Action Plan for Sustainable Plastic Waste Management, a blueprint to achieve a plastic circular economy in Bangladesh and to reinforce the 3R strategy (reduce, reuse, recycle) to avoid, intercept, and redesign plastics to achieve a green growth pathway for Bangladesh. The Action Plan acknowledges that plastic management is one of the most complex challenges. There is not one single solution, but rather a holistic, integrated approach based on a mixture of legal, financial, and communication instruments is needed (box 8.6). Additional policies broadly considered in reducing plastic pollution include the 8th Five Year Plan (2021-25) (8FYP), Regulatory Framework for Public-Private Partnerships (2019), River Master Plan (2019), Clean Dhaka Master Plan (2018–2032), and the E-Waste Management Rules (2021).

There are several ministries in Bangladesh whose mandates and activities overlap on waste management issues. At the national level, the MoEFCC is responsible for framing policy and laws, while the city corporations and municipalities are responsible for the collection, transportation, and disposal of municipal waste. The governance system for waste management in Bangladesh is presented in figure 8.11.

Figure 8.10 Timeline of policies and regulations on waste management in Bangladesh



Source: World Bank 2023.

Box 8.6 Action Plan for Sustainable Plastic-Waste Management, 2021

Based on extensive multi-stakeholder consultations, the Action Plan identifies four targets focusing on each step of the plastic life cycle to ensure a holistic approach built on circular principles and to provide the road map for action, namely:

Target 1: Achieve a 30 percent reduction in virgin-material consumption in plastic manufacturing by 2030 by facilitating circular material flows from the 2020/21 baseline;

Target 2: Phase out targeted SUPs by at least 90 percent by 2026 from the 2020/21 baseline;

Target 3: Reach a 50 percent rate of recycling plastic waste by 2025 and an 80 percent rate of recycling plastic waste by 2030 from the 2020/21 baseline;

Target 4: Achieve a 30 percent reduction in annual plastic-waste generation by 2030 from the 2020/21 baseline.

Source: World Bank 2021.

The Ministry of Environment, Forest and Climate Change (MoEFCC) has the mandate for (a) coordinating and supervising the application and implementation activities of the SWMR's provisions; (b) establishing the NSWMCC for the purpose of implementing the SWMR's provisions; and (c) approving guidelines and directives on solid-waste management framed by the DoE. The DoE is mandated to enforce environmental rules and regulations including those on SWM, promote environmental awareness, implement 3R projects, and provide services to the citizens to ensure a clean and healthy environment. The DoE has enforced the 2002 Plastic Bag Ban through unannounced inspections conducted by mobile (environmental) courts (see chapter 3 of this CEA).

The Plastic Bag Ban applies to the use, production, sale, marketing, stocking, distribution, import, and trade of plastic bags. Violation of this ban has been made punishable by imprisonment of up to 10 years and a fine of up to $9,392.75. However, polythene bags for export purposes were exempted. Although the Plastic Bag Ban was enforced well in the first two years of introduction through rigorous market monitoring and the creation of awareness among consumers, implementation of the ban was not necessarily achieved in the long term (Irin 2011). The failure can be attributed largely to a lack of institutional capacity to sustain the momentum, no effective control at the end of production, weakened market monitoring, and limited availability of practical alternatives leading to consumer reluctance. The business sector also must share responsibility for the failure since they not only opposed the ban but also showed little interest in promoting alternatives. According to DoE data, in 2021, 2022, 2023, the mobile courts seized only 125.1, 154.4, and 180.3 metric tons of polyethylene, respectively. This volume is insignificant compared to the total generation of low-density polyethylene (LDPE) in the country, which was 323 tons per day in 2020 (World Bank 2021b).

The city corporations and Local Government Institutions (LGIs) provide waste-collection systems, making the Ministry of Local Government, Rural Development and Cooperatives (MLGRDC) another key government stakeholder. The MLGRDC leads coordination with local government departments on housing and buildings, regional and rural policy, municipal and city administration and finances, and elections. Local government authorities play an important role in sustainable waste management. According to the SWMR, subnational agencies are responsible for the separate collection and management of nonhazardous solid waste from organic, construction, and demolition sites, and from medical sources.

Figure 8.11 Governance structure of integrated sustainable plastic waste management in Bangladesh

Source: World Bank.

The responsibilities of waste generators, producers, importers, and other actors have not, however, been spelled out. The Ministry of Water Resources, including the Bangladesh Water Development Board (BWDB), is responsible for water management in the country. The BWDB is responsible for implementing, operating, and maintaining water-related projects (including drainage and cleanups from plastic pollution).

The Ministry of Industries (MoInd) and Ministry of Commerce (MoC) also play central roles in promoting circularity and upstream solutions in plastic management. Through the National Plastic Industry Development Policy, 2023 (8th Draft), the MoInd identifies measures to reduce the impact of plastic waste and litter; improve the efficiency of plastics recovery, recycling, and product design; and create conditions for investments and innovations in the circular economy while reducing dependency on fossil fuels and exploring alternatives including biobased materials. The policy also endorses EPR requiring manufacturers to take responsibility for their product and packaging through all life-cycle stages, including disposal. Bangladesh imports and exports plastic and other relevant materials and products. The MoC oversees the regulation and implementation of policies regarding domestic and foreign trade including plastic products and recycled material in Bangladesh.

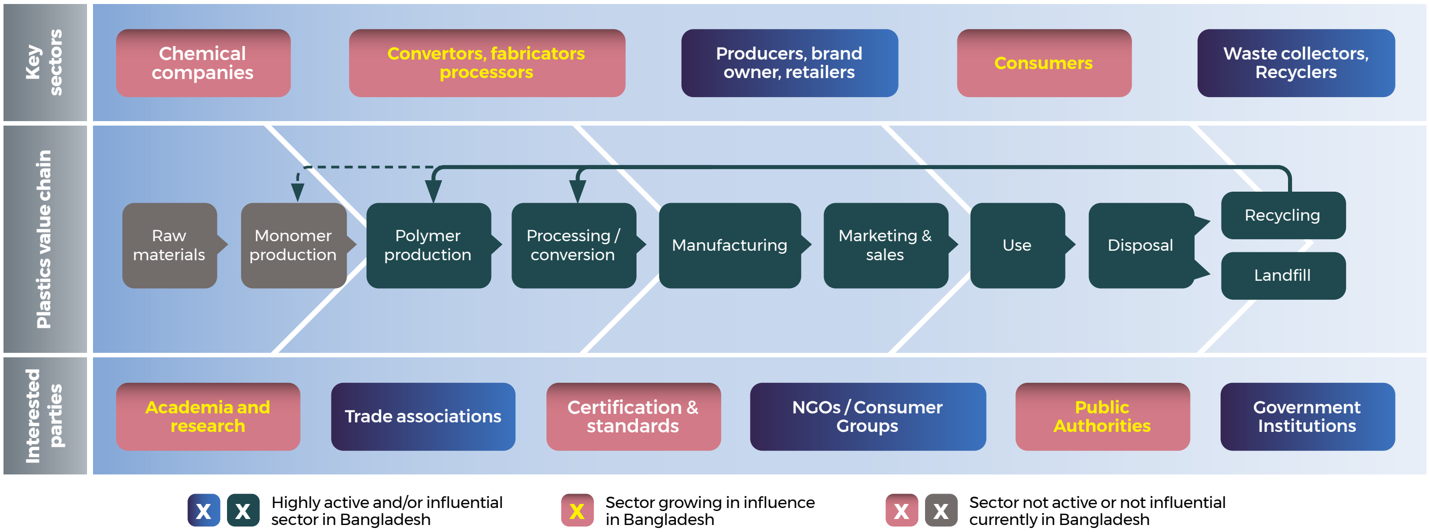
8.6 Bangladesh's plastic economy

Bangladesh manufactures plastic for both export and local use.[77] The nation's plastic industry maintains a substantial market size with an estimated value of $5 billion in 2020 (Mourshed et al. 2017). In 2018, imports and exports of plastics were valued at $1.9 billion and $1 billion, respectively (BIDA 2021).[78] A range of stakeholders play a role in creating, distributing, using, and managing plastic across its value chain (figure 8.12). The main plastic products used domestically in Bangladesh include packaging such as garment packaging, bags, and hangers; medical products such as blood bags and saline bags; and household items such as furniture, buckets, and tableware (BIDA 2021; Sultana 2019). The sectors with the highest use of plastic include infrastructure, agriculture, water management, and consumer goods (packaging) (World Bank 2021b).

Government supports growth of Bangladesh's plastic economy. For export diversification, the GoB has identified the plastics industry as a thrust sector. Official data show a 38.77 percent increase in export revenue from plastic products between fiscal 2018/19 and fiscal 2021/22 (EBP 2022). The value of plastics exported by Bangladesh has been expanding at a rate of 4.5 percent per year since 2014 and was valued at around $1 billion in fiscal 2018/19 (BIDA 2021). This $1 billion includes plastic goods as well as deemed export consisting of accessories and materials for the garment sector. The National Plastic Industry Development Policy of 2020 aims for a sector growth of 15 percent per year, raising plastics sector's contribution in total GDP to at least 2 percent by 2026 (MoInd 2020).

Both the Export Policy of 2022 (Ministry of Commerce 2022) and the National Industrial Policy (drafted in 2022) provide significant support to encourage growth. Export-orientated industries are facilitated with bonded warehouses allowing them to import materials with no duty or taxes (National Board of Revenue 1969). The government reduced import taxes for raw materials for plastic manufacturing from 25 percent in 2015 to 5 percent in 2022, while the manufacturers proposed to reduce the import duty on raw materials even more to 1–3 percent (Business Standard 2022).

Figure 8.12 Stakeholders active across Bangladesh's plastics value chain



Source: World Bank.

Bangladesh has an active plastic-recycling industry, mostly concentrated in Dhaka. Informal recycling units, which consist mostly of small businesses and self-employed persons with little or no legal recognition, low capital investments and widespread collection systems, exist in urban and rural areas. The recycling rate for plastics in Dhaka is 37 percent (World Bank 2021b). In 2022, there were 5,000 plastics-recycling factories in Bangladesh, although only 300 were registered (Chakma 2023; Daily Star 2022; Sultana 2019). The plastic-recycling sector in Dhaka employs almost 5,400 workers (almost 0.3 percent of Bangladesh's total employment) (World Bank 2021b). A network of feriwalas (collectors); wastebin tokais (youth collectors); bhangari (waste sorting, cutting, and pelletizing enterprises) (figure 8.14); brokers; and mohajans (wholesalers) are involved in collecting, sorting, cutting, and often transporting plastic waste.

In Dhaka, there are reported to be about 90,000 active informal waste workers. The sorting is done manually (see figure 8.13), while cleaning, cutting, and pelletizing are done mechanically. This waste is pelletized in more formal industrial complexes mostly in and around Dhaka and reused in local industries or exported abroad as recycled plastic flakes.

The recycling sector faces the following challenges: (a) plastic waste is primarily sorted by product type (for example, bottles and containers) rather than by resin (for example, PP and PET), thereby affecting the quality of the recycled output, making it potentially unsuitable for some applications; (b) only 10 percent of recycling facilities have higher quality "hot wash" facilities. The remaining exporters rely on less expensive "cold wash", which often includes direct use of running river water and which may contaminate plastic and make downstream uses difficult.

Figure 8.13 Manual sorting of postconsumer plastic waste in Dhaka, 2023 | Sujat Nagar slum in Dhaka, 2016

Source: ©Nina Tsydenova / World Bank — Dominic Chavez/World Bank.

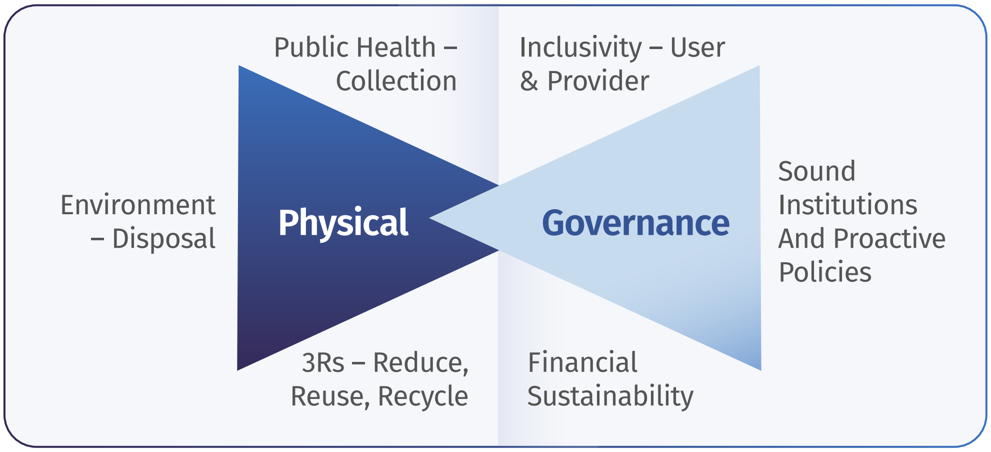
Recycled plastics can be utilized domestically but are mostly exported. The GoB provides a 10 percent cash incentive on the export value of plastic products including recycled PET flakes[79] (BIDA 2021). Traditionally, plastic-recycling companies in Bangladesh have exported the flakes (Sultana 2019). PET recyclers export different types of recycled plastics to Austria, China, India, the Philippines, Taiwan, Thailand, Ukraine, Vietnam, and some European countries at a price that is a much higher than the domestic market (World Bank 2021b). In recent years, the low price of oil has decreased the price of virgin PET flakes, making PET recycling less lucrative in Bangladesh (World Bank 2021b).

The global shift in the textile industry—from agro-based to recycled-plastic-based yarns—has provided a unique opportunity for Bangladesh to transition to recycled PET-based textile manufacturing. In 2022, the Bangladesh Textile Mills Association (BTMA) reported that a set of local manufacturers have invested BDT 16.7073 billion to make yarn and fabrics from recycled plastic bottles (Apparel Resources 2022; Mridha 2022). Establishing comprehensive recycling systems in Bangladesh encompassing various technologies and materials could result in the development of a domestic recycling market generating an annual revenue of $1.2 billion, which will create approximately 20,000 jobs through introducing new skill-based positions and by formalizing informal jobs in waste management and logistics (McKinsey & Co. 2021).

8.7 Policy recommendations for integrated plastic-waste management

Bangladesh faces a serious environmental challenge due to unmanaged plastic waste. To address this issue, the country needs a comprehensive and coordinated strategy that combines legal, financial, and communication measures. This section presents the main policy recommendations for an integrated waste-management framework (including plastic) (figure 8.14). These policy recommendations are consistent with the roadmap developed and the four main targets outlined in box 8.6.

Figure 8.14 Framework for integrated waste management (including plastic)



Source: Wilson et al. 2015.

The following recommended actions are based on the ongoing analytical work and will require financial resources to support their implementation and enforcement.

- Develop an integrated waste-management framework to address the growing problem of plastic and municipal waste overall. Integrated waste management involves waste collection, disposal, and recovery, as well as stakeholder engagement, policy changes, community-led initiatives, and innovative financing. The framework should also encompass stricter requirements for incineration and improved landfill site management practices. The goal of integrated waste management is transition to a circular economy, where waste is minimized, reused, and recycled, and its environmental and social impacts diminished.
- Support research and development on alternatives to single-use plastics, specifically LDPE and PS, in order to eliminate unnecessary plastic packaging and reduce its use by promoting the use of alternative materials. It is important to invest in new plastic materials that are practically biodegradable or compostable, but a detailed comparison of LCA and consumer acceptance rates should be conducted before introducing any new material.
- Develop a strategy to effectively implement the ban on plastic bags and extend its scope to other single-use plastic items. This will require clear definition of the ban's scope, enforcement, and monitoring; judicial support; access to alternatives; development of national standards for biodegradable bags; and education and outreach.
- Finalize and pilot extended producer responsibility (EPR) guidelines as per SWRM 2021 to enable industry co-funding of plastic-waste collection and recycling systems. This will require the development and effective implementation of the EPR scheme, mechanisms for monitoring and evaluation, defining the budget for the institutions tasked with implementation and enforcement, establishing technical norms and standards supporting the regulation, and conducting the technical studies that underpin the packaging materials used to enhance recycling in the country.
- Promote waste segregation at the household level, develop the missing infrastructure, and conduct behavior-change campaigns. This will require strategies and awareness-raising campaigns to educate and motivate citizens to sort waste at the household and individual levels.
- Harmonize plastic-management policies to promote circular economy. This will require establishing a unified approach to harmonize plastic-pollution control efforts into a cohesive, holistic policy approach, which will address all stakeholders of the plastic value chain and all relevant government agencies.
- Review options and develop a strategy to reduce ALDFG pollution and harmonize with ongoing plastic waste policy and management schemes. This will require a review of the current options to reduce ALDFG and integrate it into ongoing efforts to reduce plastic waste in Bangladesh.
- Utilize plastic cleanup and recovery schemes to reduce legacy plastic waste and mitigate associated impacts. This will require recovering legacy plastic pollution for waste management and recycling.
- Create a monitoring system for SWMR 2021 and targets of the Plastic Action Plan from baseline. This will require the development of a monitoring framework considering the objectives of the SWMR 2021 and the strategies and targets set in the plastic action plan.

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Endnotes

73 The 2020 consumption figure is based on a detailed survey on the waste composition of households and landfills in Dhaka City in 2020, which was extrapolated based on projections of urban-waste compositions of 2005 and 2014 to estimate the overall urban plastic consumption in Bangladesh.

74 This is especially true for the Aedes aegypti species of mosquitoes—the principal vectors implicated in the transmission of dengue disease.

75 Societal cost refers to loss of income, the costs associated with commuting back and forth to hospital/doctor stays/visits, and the costs of additional services/goods needed to aid the patient, and so forth.

76 Primary microplastics are engineered to be in this size range while secondary microplastics are produced through the fragmentation of larger plastics. Common sources of primary microplastics include microbeads from personal care products, such as shampoo, face wash, and toothpaste, and plastic preproduction pellets, which are used to produce plastic items. Due to weathering from physical stress, waves, sunlight, and changes in salinity or temperature, plastic waste produces secondary microplastics and nano-plastics.

77 Manufacturers produce plastic goods and packaging materials using imported virgin and recycled resins as raw materials.

78 Deemed exports refers to the indirect export of plastic goods including via the ready-made goods (RMG) industry in Bangladesh (including hangers and packaging).

79 To receive cash incentives from the Bangladesh Bank, exporters will have to show certified “freight on board value” and have membership in the relevant registered association.

CHAPTER 9. ENABLING THE ENVIRONMENT FOR GREEN FINANCING IN BANGLADESH

9.1 Introduction

Bangladesh's environmental agencies face significant budget constraints to implement their mandates. Line agencies also struggle with limited resources to implement pollution-abatement measures and improve environmental performance in their respective sectors. Companies do not have adequate incentives for complying with environmental regulations or investing in research, innovation, and adoption of green technology (chapter 3). In parallel, financing climate action alone for Bangladesh is estimated to require more than $200 billion over the next two decades.[80] Complementary plans and initiatives will also require billions of dollars to be fully implemented. According to research performed for the Perspective Plan 2041 (GoB 2020b), to achieve green growth, the country needs to increase its spending on programs related to environmental protection and climate change to 3 percent of GDP by 2031 and to 3.5 percent of GDP by 2041 (Ahmed 2017).

Green financing is essential to maximize resources for both public and private initiatives for clean, efficient, and resilient production and services—key pillars for improving environmental quality and green growth. This chapter identifies the barriers for accessing green financing, especially to address environmental priorities, and proposes interventions to facilitate the flow of resources from green finance suppliers to sectors pursuing such resources.

9.2 Green finance

Green financing aims to ensure sufficient and adequate financial flows to support the implementation of a green growth strategy, including key interventions to raise revenues for environmental management and address the country's environmental priorities. The term "green finance" is traditionally used in reference to financial tools such as green bonds, green loans, or carbon-market instruments, among others (Sachs et al. 2019). However, financing green growth goes beyond the establishment and use of financial instruments and should consider the demand side for green development with the supply of resources to do so. Both the demand and supply sides of green finance are necessary for the advancement of efforts that internalize negative environmental externalities and foster new environmentally friendly investments.

Thus, when discussing green finance, this chapter refers to both the supply and demand of financing for the promotion of green growth. This definition aligns with that of Bangladesh Bank (BB) for sustainable finance: "any form of financial service that includes investment, insurance, banking, accounting, trading, economic and financial advice integrating environmental, social and governance (ESG) criteria into the business or investment decisions for lasting benefits of both clients and society at large" (BB 2020, 12).

However, Bangladesh lags other emerging markets and developing economies in green finance due to structural weaknesses (World Bank 2022a). To better understand how to address those weaknesses, this chapter focuses on the enabling environment for promoting green financing in the country. To do so, the chapter will rely on the Green Financial Value Chain (GFVC), a framework that maps the main stakeholders, linkages, and processes associated with an environment that is more conducive for the flow of green finance in Bangladesh (see figure 9.1). The GFVC depicts a framework to understand green finance in Bangladesh and helps to identify the bottlenecks its stakeholders face and the role they could play to foster the channeling of financial resources to environmentally sustainable initiatives. These barriers and gaps are summarized from the borrowers', financial institutions', and government's perspectives, but they also involve other stakeholders like consumers, investors, and international organizations supporting a green growth agenda in Bangladesh.

9.3 Key green finance stakeholders in Bangladesh

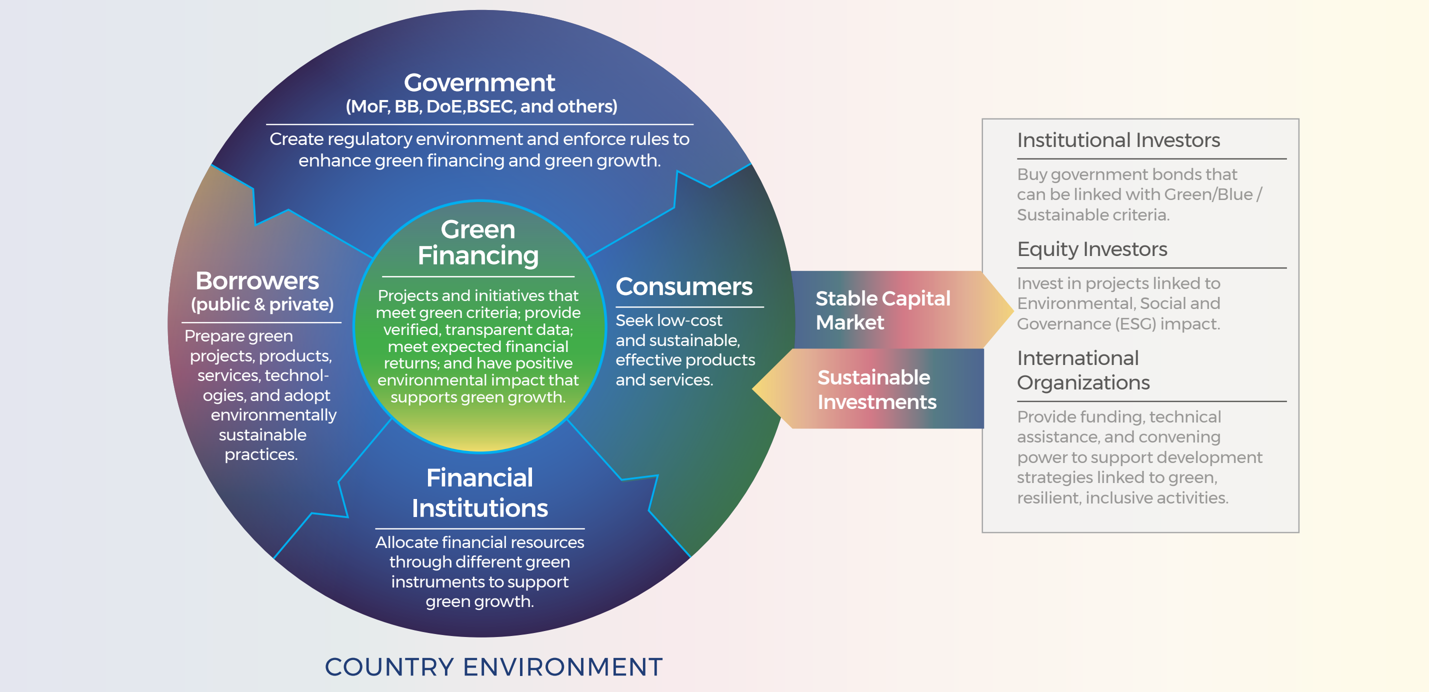
The 2020 Bangladesh Climate Fiscal Framework presents information about a wide range of climate-related policies, plans, strategies, and different sources funding them. The framework partially identifies the demand and supply for climate-related funds, including the resource allocation made by 25 ministries and government agencies, the financial sector, and NGOs/CSOs, among others (MoF 2020). However, the framework does not present a comprehensive list of sources financing GG—which includes but is not limited to climate actions—and important information gaps remain. In contrast to public finance, private-sector commitments to climate and environmental finance are not well mapped in Bangladesh.

Regarding green banking, the BB has led the country through innovative regulations, policies, and incentives. Through its Sustainable Development Department and with technical support from the IFC, the BB issued its Green Banking Policy Guidelines for Banks (2011) and for Non-bank Financial Institutions (NBFIs) and New Banks (2013), and Sustainable Finance Policy for Banks and Financial Institutions (2020). Among these measures, the BB has established targets for direct green finance and sustainable finance at 5 percent and 15 percent of the total funded loan disbursements or investments made by banks and FIs, respectively[81]. Loans and investments are being directed to projects and initiatives in renewable energy, energy efficiency, alternative energies, waste management, recycling, recyclable products, and green brick manufacturing, among others. The BB has also pioneered the use of green central banking as an instrument to operate different green funds at concessional rates, like green refinancing schemes with its own resources and development-partner financing to provide concessional loans to eligible green investments.

Yet, structural weaknesses in Bangladesh's banking system have hampered the volume and range of green finance instruments. For fiscal year 2021, the share of green finance was 4.41 percent ($1.2 billion) of the total term loan disbursement. This is a sharp increase over previous years (figures 9.2 and 9.3), but low compared to emerging markets where the average is about 7 percent (World Bank 2022a). The pipeline of green projects is lean, and financial institutions have difficulty identifying green assets and projects due to a lack of clear standards and labels. The banks also rely on short-term deposits for funding, which does not position them well to finance climate and other green projects, most of which are long-term. Furthermore, even if banks were to meet the green finance target, this would amount to financing of around $600 million per year, a small dent in the financing gap[82] (World Bank 2022a).

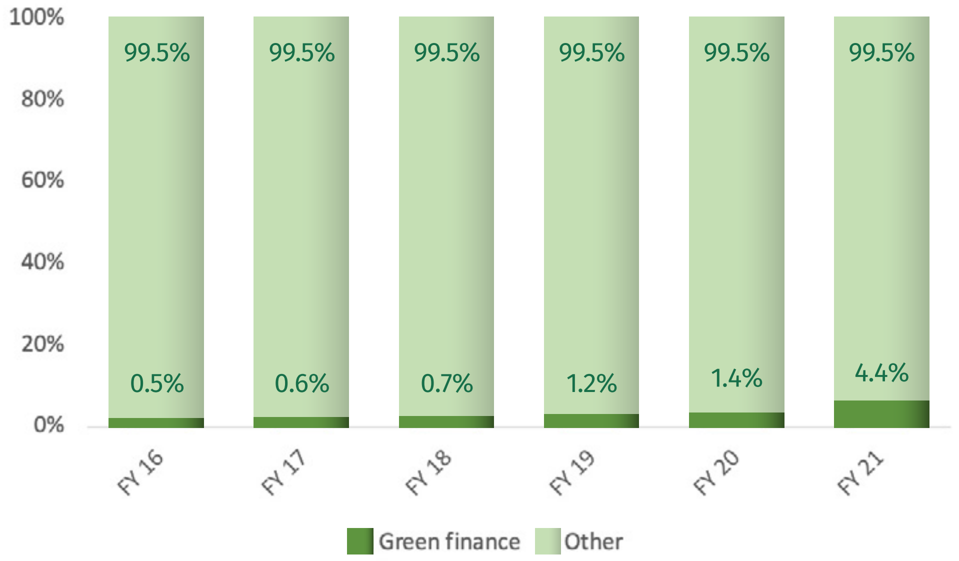
The GoB remains the most relevant source of financing for environmentally sustainable development and green growth in general. In 2009, the government created the Bangladesh Climate Change Trust Fund from its own resources to combat climate-change impacts in the country. The fund received $453 million and helped to implement the Climate Change Strategy and Action Plan 2009. In 2021, at least 8.1 percent of the government budget (0.8 percent of the country's GDP) was directed towards addressing vulnerabilities related to environmental sustainability, adaptation, and mitigation. The thematic areas where these resources were invested included food security, social protection, and health; comprehensive disaster management; infrastructure; research and knowledge management; mitigation and low-carbon development; capacity building; and institutional strengthening (MoF 2020). The total public spending of the core ministries dealing with water, land, and environment-related services constituted about 0.39 percent of GDP that same year. These efforts, although important, are insufficient. Additionally, budget allocation across and within sectors does not necessarily respond to the country's environmental and other green growth priorities (chapter 3). (See figure 9.2.)

Figure 9.1 Green Financial Value Chain (GFVC)



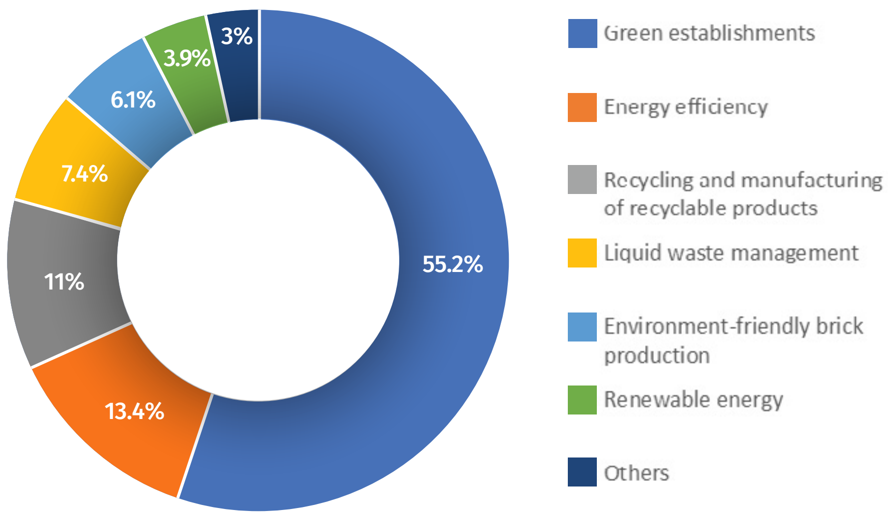
Source: World Bank.

Figure 9.2 Green financing's share of total term loan disbursements



Source: Bangladesh Bank 2022.

Figure 9.3 Green financing by category

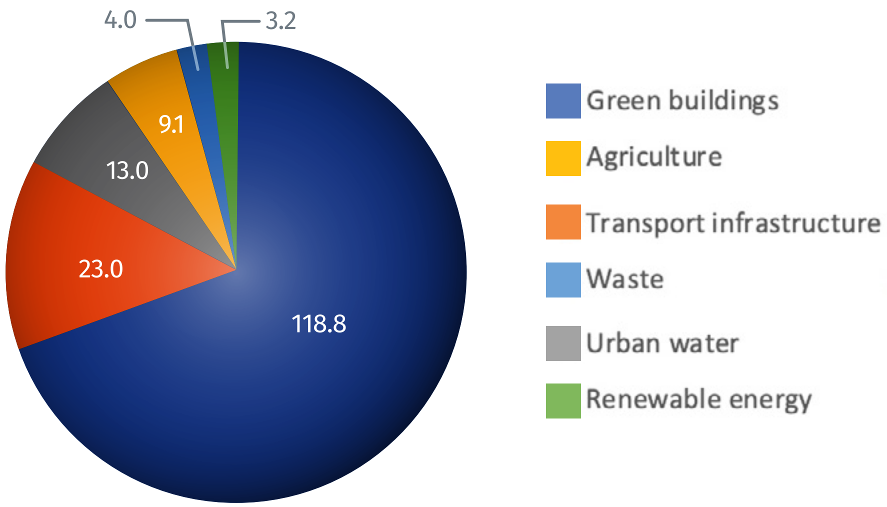


Source: Bangladesh Bank 2022.
Note: "Others" includes green Cottage, Micro, Small, and Medium Enterprises (CMSMEs), green agriculture, solid-waste management, green Socially Responsible Financing (SRF), and alternative energy.

9.4 Demand for green financing

Financing climate action alone for Bangladesh is estimated to require at least $176 billion over the next two decades. Estimates from Bangladesh's NDC to the Paris Agreement indicated that $67 billion in funding was needed for the country's climate-adaptation measures between 2015 and 2030 (GoB 2020b). According to the 2021 NDC Update, approximately $32 billion would be required to meet unconditional mitigation objectives and an additional $144 billion required to meet conditional objectives during 2021–30 (World Bank 2022b). Investment of at least $200 billion for the next two decades is needed for Bangladesh to reach its top-tier climate-mitigation targets and ambitions (Bangladesh Bank and IFC 2021) (see figure 9.4).

Figure 9.4 Bangladesh's Climate-Smart Investment Potential (2018–30) | *$, billions*



Source: IFC 2019.

In addition, Bangladesh has a myriad of plans and initiatives that will demand significant economic resources, like the Mujib Climate Prosperity Plan ($89.7 billion by 2030) and the Bangladesh Country Investment Plan for Environment, Forestry and Climate Change ($11.7 billion). The Bangladesh Delta Plan 2100 (BDP), which intends to secure the future of water resources and mitigate the likely effects of climate change and natural disasters, is estimated to require $38 billion by 2030 (in 2015 prices) for physical investments and institutional strengthening for implementation and monitoring (World Bank 2022b).

Complementary plans and initiatives will also require billions of dollars to be fully implemented. The implementation of the Delta Plan 2100 will require about 2.5 percent of the total domestic income every year until 2030, with its first phase costing around $37 billion. According to research performed for the Perspective Plan 2041, to achieve GG, Bangladesh needs to increase its spending on programs related to environmental protection and climate change to 3 percent of GDP by 2031 and to 3.5 percent of GDP by 2041 (Ahmad 2017).

Finally, interventions to strengthen Bangladesh's environmental management system and address major environmental health-risk factors—ambient and household $PM_{2.5}$ air pollution, lead exposure, and inadequate drinking water, sanitation, and hygiene—will require considerable resources (chapters 2 and 3)**.** Detailed benefits and costs analysis of interventions that promise the greatest environmental health improvements or benefits per taka spent on the interventions are discussed in chapter 5 of this CEA. For example, the cost of the comprehensive $PM_{2.5}$ control measures for which benefits exceed costs is $1.3 billion (Tk 109 billion) per year. Green financing could be directed to interventions that contribute to addressing those health risks.

9.5 Barriers to channeling green finance into Bangladesh's green growth projects

Bangladesh has taken substantial steps to spur a green economy by, among other steps, adopting green policies, programs, and projects; establishing green regulations; and extending green incentives. However, several institutional bottlenecks remain that impede the implementation of Bangladesh's objective of growing in an environmentally sustainable way. Within this context, financial institutions (FIs) continue to perceive "green" as riskier than "non-green" investments, while *borrowers* face a huge hurdle in adopting and financing green practices. At the same time, polluters do not feel the need to change their practices. This has resulted in insufficient financial flows, an inadequate pipeline of projects, and subsequently, ineffective green growth outcomes.

Listed below are key bottlenecks and barriers that have been identified by examining the challenges faced by stakeholders mapped in the GFVC in the processes for financing green growth in Bangladesh. Conversations with key stakeholders as well as a review of previous studies carried out on green financing have been considered in this report when identifying the root causes of impediments to financing Bangladesh's green growth. Addressing these bottlenecks is key to creating an enabling environment for advancing green financing in the country, as discussed in the next section.

Borrowers face significant hurdles in adopting and financing green practices, such as these:

- **Lack of capability to adopt and implement green practices and technologies.** Adopting and implementing green practices and technologies requires borrowers to employ new sets of skilled resources (often new personnel or additional training) and new management systems. Without adequate understanding of those green practices and technologies, and without adequate experience in successfully operating them, entrepreneurs' capacity to go green is affected (Cirera and Maloney 2017). In Bangladesh, the Sustainable Enterprise Project provides an example of the use of green finance and the development of capabilities in microenterprises to adopt environmentally sustainable practices and technologies (box 9.1).

Box 9.1 Financing Environmentally Sustainable Practices in Bangladesh

The World Bank's Sustainable Enterprise Project (SEP) provides access to microenterprise (ME) loans through the Palli Karma-Sahayak Foundation and its partner NGOs to adopt cleaner and greener methods of operation. Since 2018, the SEP has directly supported 60,000 MEs across Bangladesh that have received loans and trainings for the adoption of environmentally sustainable practices (ESP). Close to 33,000 MEs have adopted at least one ESP, including practices that advance waste management (reduce, reuse, and recycle); the reduction of water and air pollution; and the use of energy saving technologies; among others. In addition, the SEP helps MEs to adopt practices that reduce occupational health and safety risks and improve workers livelihoods. These practices include the use of personal protection equipment (PPE); access to safe drinking/potable water, hygienic toilet, and safe handwashing facilities; improvement of air circulation systems with ventilation at the workplace; and access to sufficient lighting; among others. By providing basic services and health to workers, both workers and MEs can increase their productivity and ability to take up economic activities in environmentally sensitive, climate-vulnerable, and disaster-prone areas. The SEP has also encouraged non-banking financial institutions to support green growth initiatives and shift their portfolio assets to include environmental protection, pollution and contamination reduction, and better workplace safety—considerations that are too often overlooked among Bangladesh's MEs.

Source: https://projects.worldbank.org/en/projects-operations/project-detail/P163250?lang=en

- **Limited knowledge and capacity to prepare bankable green projects.** A BB study showed that 62 percent of SMEs do not maintain balance sheets, and those SMEs that maintain balance sheets lack audited balance sheets (BB 2013). In addition, small and medium enterprises (SMEs) are usually unable to provide loan collateral and cannot always prove there is enough demand for the green products and services they provide. Those factors increase investors' concerns about the financial viability of investments in polluting sectors (for example, agriculture and industry) (Rahman, Khan, and Farin 2019; UKaid 2017a).
- **High capital investment requirements for going green,** either for new technology or to retrofit existing equipment in certain polluting industries. Transitioning to a cleaner production path entails additional investment, including importing machinery, accessories, and other goods, usually with long return-on-investment, thus making green ventures expensive. In addition, administrative hurdles, fees, and issuance costs, among other transaction costs, reduce investors' incentive to fund green projects and stop entrepreneurs from asking for funding (UKaid 2017a; Vivid Economics and Climate Bonds Initiative 2019).
- **Stringent requirements to borrow.** Borrowing is hard due to stringent due diligence on the issue of loanees' creditability, track record of business, environmental and social safeguard issues, strict guidelines on collateral, short repayment period, and unattractive refinancing schemes offered by banks and FIs.
- **Low demand for green products** with consumers opting for cheaper goods. Polluting sectors in Bangladesh (for example, agriculture and manufacturing) can operate at lower cost, providing more-competitive goods and services for the domestic economy. Green products and services may be comparably more expensive due to up-front costs. Consumers tend to be unaware when goods are produced by polluting industries and negatively impact the environment. Most sectors identified in Bangladesh as eligible for receiving green finance have low investment demand, a situation driven in part by consumers' lack of interest in green products and solutions, and entrepreneurs' weak awareness of the opportunities of going green (UKaid 2017a).

FIs continue to perceive green projects, businesses, and technologies as risky endeavors. FIs face these challenges:

- **Structural weaknesses in the financial sector** limit the capacity of finance to reach underserved segments, like CMSMEs, economic sectors perceived as risky, and long-term projects. These structural weaknesses include the interest-rate cap, licensing framework, corporate and regulatory governance structures, credit-underwriting capacity, operational inefficiencies, and underdeveloped capital markets (World Bank 2020).

- **Low risk appetite and short-term focus** contribute to slow green loan disbursement. The BB had set a 5 percent loan disbursement target, which FIs have been unable to meet. In Bangladesh, 8.1 percent of total loans in September 2021 were non-performing loans (NPLs)—on par with India but much higher than Nepal and Sri Lanka.[83] In a systemic loan-default culture, such as in Bangladesh, banks tend to refrain from investing in unproved practices, technologies, and business models with unknown risks. At the same time, most green projects have long payback periods. Loans traditionally focus on short-term monetary gains and do not consider long-term environmental impacts due to vague policies and lax enforcement (UKaid 2017a). Although green projects address negative environmental externalities, lenders see little commercial value in that.
- **High cost of doing business** attributable to on-site visits to projects in the green portfolio and the need for specialized human resources to inspect and verify project activities. Post monitoring of projects funded by banks under green finance requires continued oversight, which is an added burden on the traditional banking culture in place in Bangladesh.
- **Inadequate in-house technical capacity.** The processing and administering of loans for green projects suffers from a lack of technical capacity to assess environmental and social goals (ESG) risks and the future potential of green technologies. The BB introduced guidelines on environmental and social-risks management in 2017. However, Bangladesh's credit and financial institutions still need to improve their capabilities for evaluating the environmental and social risks associated with green projects and the financial implications of those risks (Hossein 2018). Additionally, in the absence of an institutionalized third-party monitoring and verification system in Bangladesh, banks find it hard to keep track of whether borrowers have adequately addressed environmental issues. Consequently, banks are reluctant to finance green projects without substantial collateral to reduce the perceived risk to the bank. Financial institutions could learn from successful cases already present in Bangladesh in the garment industry (box 9.2).

Box 9.2 Resource efficiency in the garment industry in Bangladesh

Companies can play a major role through corporate social responsibility (CSR) and supply-chain initiatives. Leading international brands in the textile and apparel industry have since 2014 been closely involved with the successful Partnership for Cleaner Textile (PaCT) program financed by the International Finance Corporation (IFC). PaCT works with global apparel brands and the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) to support the entire textile value chain. This includes spinning, weaving, wet processing, and garment factories in adopting Cleaner Production (CP) practices and engages with brands, technology suppliers, industrial associations, financial institutions, and government to bring about systemic and positive environmental changes (https://www.textilepact.net/what-is-pact.html). Since its inception, PaCT has worked with more than 338 factories to reduce freshwater consumption by 25 million m^3/year and cut wastewater discharge by 21.08 million m^3/year. These factories now save 2.5 million MWh/year in energy and avoid greenhouse gas emissions of up to 489,796 tons/year of CO_2. To facilitate investment in resource efficiency technologies, PaCT has developed financial mechanisms and products to enable access to finance for textile factories and their value chain. It has also engaged in matchmaking between banks, businesses, and technology suppliers to build capacity for identifying and assessing bankable projects. PaCT advocacy also helped to create the BB's Green Transformation Fund, a $200 million refinancing scheme that facilitates access to finance for importing capital machinery and accessories for environment-friendly initiatives. Those initiatives include water-use efficiency in wet processing, water conservation and management, waste management, resource efficiency and recycling, renewable energy, energy efficiency, heat and temperature management, air ventilation and circulation efficiency, and work environment improvement initiatives.

Source: Bangladesh PaCT: Partnership for Cleaner Textile. https://www.textilepact.net/

The GoB lacks institutional structures for implementing its policies and targets and for effectively holding polluters responsible. Specifically, it faces the following challenges:

- **Low interagency coordination to advance a comprehensive national green growth strategy** backed by a national action plan and green finance policy to support Bangladesh's green growth commitments. With several agencies and ministries playing different roles that shape environmental management and investors' decisions to invest in the country,[84] Bangladesh lacks a dedicated body with the specific objective of improving and securing access to local and international green finance (UKaid 2017a). Chapter 3 of this CEA highlights some of the coordination failures government agencies experience when defining environmental priorities and action plans across relevant sectors. BB initiatives succeeded in creating a framework for the banking sector, but the enabling environment for ushering in a new development paradigm is still missing. Without a dedicated body, coordination failures and other inefficiencies may arise, making it difficult to advance a coherent national green finance strategy that connects all the existing elements that could help advance environmentally sustainable development. The lack of a coordinating body also contributes to deficiencies in monitoring and enforcement. Such deficiencies limit incentives for polluting industries to make green investments and improve their environmental performance, and for investors to provide adequate resources for green projects and initiatives.

- **Lax enforcement mechanisms to punish environmental offenders** have profound implications for entrepreneurs willing to go green. Deficiencies in existing regulations and weak environmental monitoring and enforcement have provided limited incentives for polluting industries to make green investments and improve environmental performance through new green products and services (World Bank 2021). Without the impetus to acknowledge and internalize their actions' social costs, Bangladesh's industries can operate without consequences for the pollution they cause. Chapter 3 discusses the institutional shortcomings facing the Department of Environment (DoE), the country's main responsible agency for environmental protection and for penalizing companies or individuals for not complying with environmental standards or for damaging ecosystems. Inadequate organizational structure, insufficient budgetary and human resources, challenges with coordination across agencies and with local governments, and limited environmental data management and limited evidence-based decision-making are some of the key challenges that need to be addressed first before the DoE can enforce existing regulations and guidelines for activities affecting the environment. In other countries, like Korea, automated emissions-monitoring systems are in place to monitor emissions, charge polluters, and inform policy (box 9.3).

Box 9.3 Korea's automated emissions monitoring system

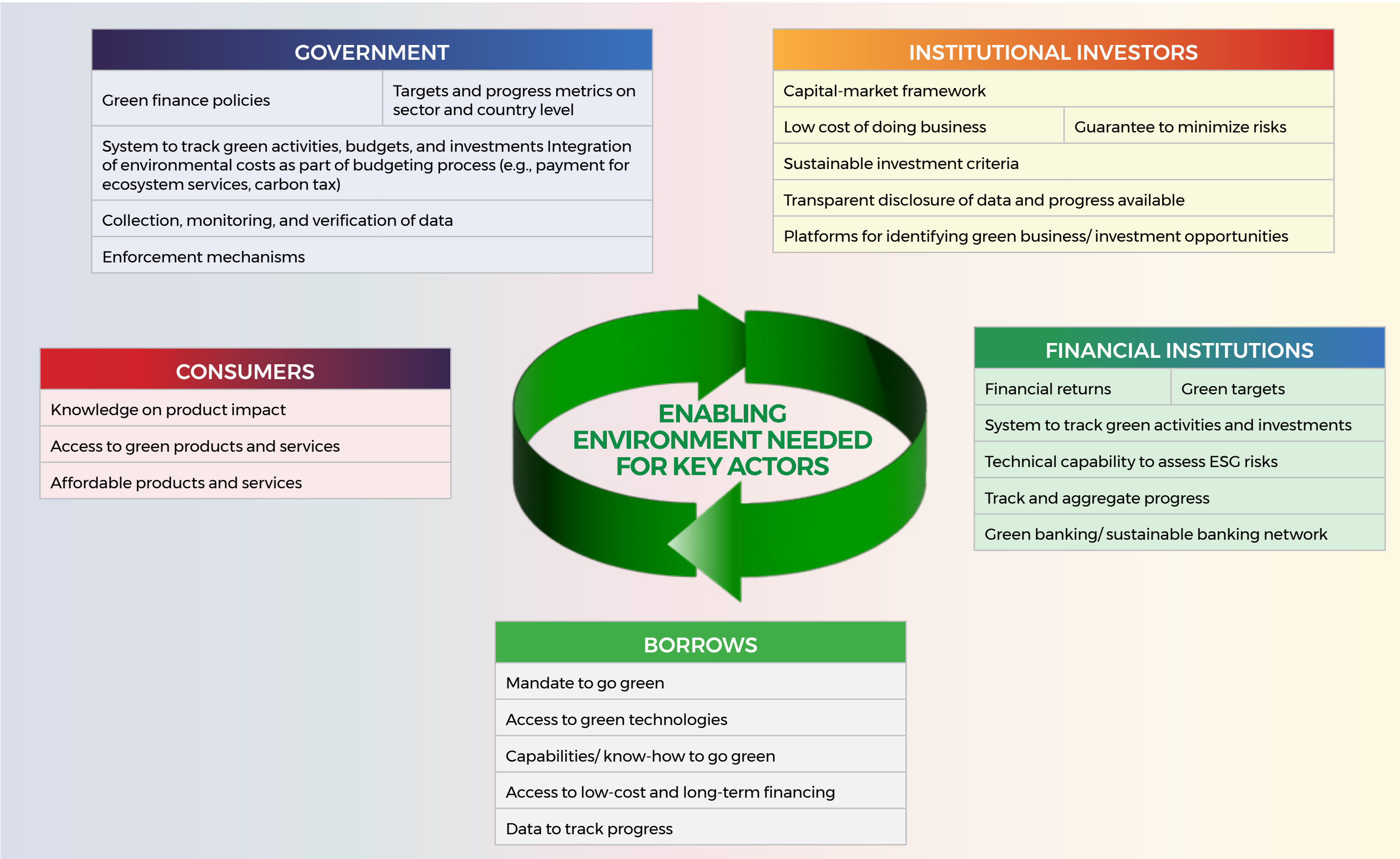
The Korea Environment Corporation (K-eco), a quasi-governmental organization, manages a comprehensive data measurement and analysis system. For example, CleanSYS measures air pollutants emitted from stacks in real time using an automatic stack measuring device that connects online to K-eco control centers. While K-eco manages this monitoring network and analyzes the data, this information is then used by local government and the Ministry of Environment to charge fees and penalties from polluters and to inform policy formulation. The data are also shared with the Korea Environmental Industry and Technology Institute (KEITI), the Korea Institute for Advancement of Technology (KIAT), and other public agencies for purposes of financial decision-making. The point-source pollution monitoring system was initially manual but a telemonitoring system was introduced to reduce the administrative burden and enable an early warning and real-time data disclosure.

Source: https://www.keco.or.kr/en/core/climate_air3/contentsid/1948/index.do

- **Inadequate expertise to evaluate green technologies and investments** within the GoB, as well as in FIs assessing the viability of green investments. Further, Bangladesh at present lacks a dedicated institution to assess and evaluate green technologies that borrowers may want to adopt for managing their enterprises' pollution (UKaid 2017b).
- **Lack of a project pipeline to attract investment in green sectors (for example, transport and urban planning).** Currently, the GoB lacks a government institution to collate projects to share with donor agencies that might invest in green projects. To promote green growth, investors need better information regarding viable, commercial projects that promote green growth (Vivid Economics and Climate Bonds Initiative 2019). The GoB could help to develop such a pipeline by providing assistance to entrepreneurs when creating development plans, project ideas, and investment plans, as well as financial disclosures, since these steps are difficult and costly for businesses (IFC 2016).

To support green growth, players along the GFVC require an enabling environment that is more conducive to connecting the demand for and supply of green finance. Figure 9.5 below presents an inventory of the key components of the enabling environment needed for financing GG in Bangladesh. These components are elements that need to be in place before each of the main stakeholders of the GFVC can maximize its contribution to the advancement of green finance in Bangladesh. Having those key elements in place requires a well-coordinated response from different actors and having proper incentive structures in place.

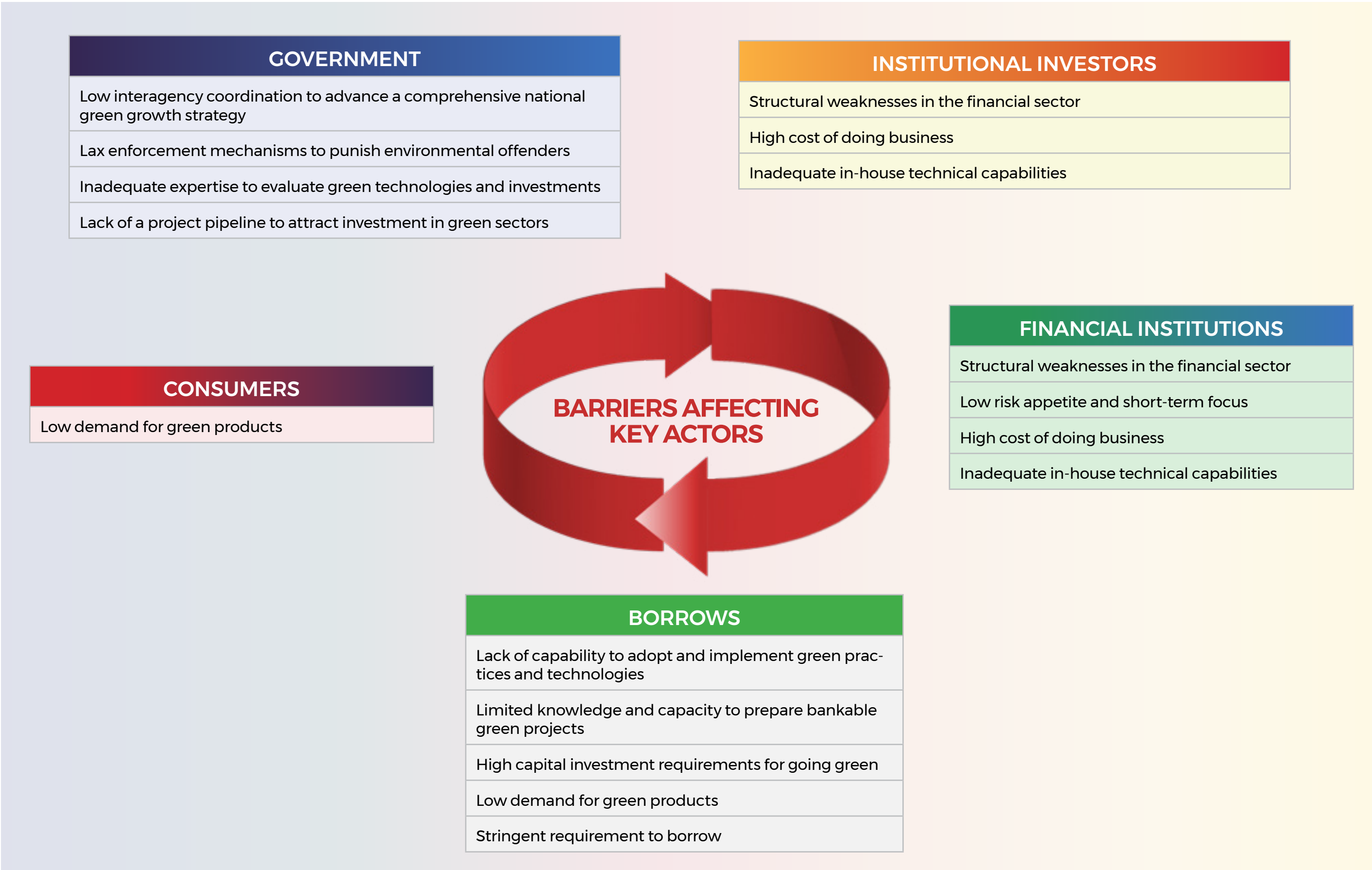
Figure 9.5 Components of the enabling environment needed for financing green growth in Bangladesh



Source: World Bank.

To pinpoint the main areas for intervention, the barriers identified through the GFVC are "superposed" on the enabling environment (figure 9.6). Figure 9.6 highlights the key barriers faced by each of the main stakeholder groups in financing green growth in Bangladesh. Eliminating or substantially reducing these barriers can help align the supply of financing with sectors that need to go green (for example, environment, infrastructure, transportation, manufacturing, and agriculture). Addressing those bottlenecks will require a well-coordinated response from key ministries and government agencies—a response that enforces regulations, establishes incentive structures, and fosters strong environmental technical expertise within both the government and the private sector. These actions will stimulate adoption of green practices and technologies and grow green businesses—essentially creating a pipeline of projects requiring green financing. Importantly, these actions would concurrently make FIs better able to identify the future potential of green investments.

Figure 9.6 Barriers affecting key actors when financing green growth in Bangladesh



Source: World Bank.

Closing the gap between those needing financing and those providing it is central to promoting green growth in Bangladesh. Areas of action are outlined in the next section (a) to lower the barriers in financing green growth and (b) to create an enabling environment to effectively fund green growth in Bangladesh.

9.6 Recommendations

To promote an enabling environment that facilitates the flow of resources from green finance suppliers to sectors pursuing such resources, this chapter identifies three types of recommendations and associated actions, as presented below. An action plan, consisting of multiple policy alternatives from institutional to regulatory components, is presented in appendix P.

Recommendation 1: Create a governance framework for green growth

Adopt a broad-based national green growth strategy and a national action plan backed by a commensurate set of regulatory and institutional frameworks. Building on the 8FYP, for Bangladesh to carry forward its national goal for promoting green growth, necessary first steps are a national green growth strategy and a national action plan for green growth that include clear goals and subgoals and the right mix of regulatory and institutional frameworks that lay out roles and responsibilities for ministries and government agencies (UNEP 2017). Providing a clear guidance for transitioning to a low-carbon economy and creating a conducive regulatory and institutional environment are key to reduce asymmetries of information and diminish risks, thus creating opportunities for investors to direct green finance towards sustainable investments.

Constitute a high-level national oversight body to coordinate and monitor the progress of green growth efforts. A high-level national committee situated under the head of the government could provide essential oversight at the start of the green growth strategy regarding the implementation of green growth actions. Such a body could address coordination failures and other inefficiencies that make it difficult to advance a coherent national green finance strategy that connects all the existing elements that could help advance environmentally sustainable development. This includes addressing some of the structural weaknesses currently present in the financial sector (for example, interest-rate cap, licensing framework, and corporate and regulatory governance structures). The coordinating body could also contribute to advance monitoring and enforcement and create incentives for polluting industries to make green investments and improve their environmental performance, and for investors to commit resources to green projects and initiatives. Chapter 3 of this CEA provides examples of additional mechanisms that could improve coordination across agencies at different governmental levels for environmental priorities.

Strengthen the institutional framework to collect and analyze point-source data to (a) inform policy design and enforcement, and (b) create a pipeline of verified investment-ready projects. An adequate monitoring system, one that collects information at the source of pollution and then assembles that information centrally for verification, analysis, and disclosure, will generate a credible enforcement mechanism. Systems for collecting point-source data allow for real-time monitoring of pollution. These systems reveal environmental externalities, thus motivating businesses to manage their environmental impact. This, in turn, can stimulate competition between firms and, with adequate enforcement or public disclosure, could hold polluters responsible. In addition, the collection and analysis of point-source data can reduce asymmetries of information by making it easier for investors to track the performance of green projects and initiatives, thus enabling the creation of a pipeline of verified investment-ready projects that attract green financing to Bangladesh. Most of these efforts need to happen inside the DoE; nonetheless, other governmental organizations also play a key role in strengthening the institutional framework that allows for the use of evidence to support prioritization and decision-making (chapter 3).

Recommendation 2: Use a mix of incentives to boost environmental markets

Encourage the adoption of green practices and promote green businesses and investments with positive environmental externalities. Incentives such as *tax cuts* and *exemptions for pollution-control efforts; long-term low-interest financing* for adoption of efficient/green technologies; *subsidies*; and *preferential benefits* for eco-friendly products make it easier for businesses to adopt green practices. Clusters of industries can also be supported to provide *environmental infrastructure*, like the government of Malaysia has done with its Waste Eco Parks initiative (box 9.4).

Box 9.4 Incentives for clustering waste management in Malaysia

The Malaysian government provides an example of clustering—providing incentives to Waste Eco Parks (WEPs) to promote waste management in a more integrated manner. WEPs aim to promote waste zero by relocating recycling companies (previously scattered and dispersed across multiple industries) to a central location within a WEP. This incentive is offered to companies in the WEP program, along with companies developing infrastructure for WEPs, companies managing WEPs, and industry stakeholders involved in waste recycling, recovery, and disposal. WEP developers (companies) may receive an income-tax exemption of 70 percent on statutory income derived from rental of buildings; rental received from the use of a waste collection and separation facility; and rental received from a wastewater treatment facility located in the WEP effective for 2016 until 2025. WEP managers (companies) may receive an income-tax exemption of 70 percent on statutory income derived from activities including management, maintenance, supervision, and marketing of the WEP effective 2016–2025. WEP operators (companies) may benefit from an income-tax exemption of 100 percent for a period of 5 years on statutory income derived from the qualifying activities undertaken in the WEP or an income-tax exemption equivalent to 100 percent of qualifying capital expenditure (investment tax allowance) incurred within a period of 5 years. The allowance can be offset against 70 percent of statutory income for each assessment year. Other integrated waste-management companies that perform/invest in additional activities such as composting, storage, collection, or disposal in addition to recycling, recovery, or disposal of waste may be considered for the Green Investment Tax Allowance (GITA).

Source: Malaysian Investment Development Authority (MIDA), Malaysia's Green Technology. https://www.mida.gov.my/publications/malaysias-green-technology/

Adopt incentives that address the actual and perceived risks faced by FIs—incentives such as *guarantees* and publicly developed *eco-certifications*. Such incentives minimize the cost to FIs, which in turn would allow businesses to have easier and cheaper access to financing. *Mandates for public disclosure for information* about enterprises' green management can provide essential information for evaluating the viability of borrowers. In Korea, for example, a green certification scheme is used to reduce risks and asymmetries of information faced by financial institutions that provide green loans to the private sector (box 9.5).

Box 9.5 Green certification system in Korea

The Korea Institute for Advancement of Technology (KIAT), under the Ministry of Trade, Industry and Energy (MOTIE), plays a core administrative role as the green certification office. The certification covers technology and associated products that minimize GHG emissions and other pollutants, and specialized enterprises whose economic activities are related to green growth priorities. Governmental agencies from multiple sectors cooperate based on their green expertise for assessing applications through document review and field evaluation. Furthermore, these agencies provide operational guidance and associated incentives such as financial support and green public procurement for certified companies. The Korea Environmental Industry and Technology Institute (KEITI), under the Ministry of Environment, is one of the agencies that collects and analyzes environmental information to assess companies' environmental pollution risk (for example, violation records of pollution regulations); environmental management activities (for example, green certificates, eco-label, and ISO certificates); and environmental-management level. The evaluation results are shared with financial institutions, including banks, asset-management companies, and insurance companies for due diligence. The final evaluation results are provided to financial institutions that have signed an agreement to spread green finance.

Source: https://www.greencertif.or.kr/ptl/cDefinitionC/operating.do; https://www.envinance.kr:442/info/info.do

Boost private-sector adoption of green practices and technologies, and thereby boost the offering of green products and services. Gaps identified through this chapter will need further analysis regarding up-front financing required, estimated reduction in pollution, partnerships to implement, and so on. For example, guarantee schemes may work for some sectors. Other sectors may require a partial tax along with use of the revenues to finance supporting programs for developing green know-how, technologies, products, and industries.

Foster a collaborative institutional system to implement green financial incentives. This can provide the enabling environment to effectively connect the flow of financing to those sectors that need to go green. Sustainable public procurement can also be used as an incentive to drive markets toward sustainable production.

Recommendation 3: Strengthen institutional and borrower capabilities

Build skills and expertise on green financing across sectors, from technocrats in government agencies to FIs, and from private businesses to students. Strengthening capacity and awareness across government and financial institutions is essential for the development of supportive policies and regulations, and to overcome knowledge barriers that constrain investments in green projects. Building foundational knowledge on green aspects and impacts across ministries would support the development of the needed policy framework and analysis. Importantly, provide overall education and awareness-raising support in addressing opposition to green investments, since such opposition can constrain investment and the development of the regulatory environment needed to advance green investing.

Develop a pipeline of trainings to adopt across government, businesses, and FIs. Following are some examples of some trainings to be adopted by entrepreneurs and CMSMEs, finance providers, and government institutions: Introducing technical courses on green technologies and green businesses in vocational institutions, promoting and building service institutions to lend services to entrepreneurs on green related topics, strengthening banks' and FIs' personnel working in sustainable financial units to deal with ESG and potential of green technologies and projects, and providing trainings on sustainability and sustainable financing for government officials different levels. This could disseminate knowledge on sustainability and green finance among society and contribute to addressing some of the barriers affecting investments in sustainable projects and initiatives.

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80 This amount represents the sum of investment need/opportunity assessments in the green economy in Bangladesh from a range of sources. These include the IFC report Climate Investment Opportunities in Emerging Markets (IFC 2016), the investment needs calculated in the Bangladesh Delta Plan (World Bank 2017), and the projections for future renewable power generation investment combined with current estimates of investment cost for such technologies from the International Renewable Energy Agency (IRENA).

81 Green finance aims to reduce negative externalities and/or promote positive externalities within the scope of the environment. Aims include the adoption of greener technologies through lending products and other financial instruments made available by banks and financial institutions, with the idea of increasing the level of financial flows from the public, private, and not-for-profit sectors to sustainable development priorities. Sustainable finance includes green finance, which is one of the sustainable finance components along with agriculture, CMSME, and socially responsible finance linked to sustainability (Bangladesh Bank 2020).

82 In the past five years, net credit to the private sector from banks averaged around $12 billion per year.

83 https://www.ceicdata.com/en/indicator/bangladesh/non-performing-loans-

84 Relevant ministries and agencies include the Bangladesh Bank (BB); Bangladesh Investment Development Authority (BIDA); Ministry of Agriculture; Ministry of Commerce (MoC); Ministry of Environment, Forest and Climate Change (MoEFCC); Ministry of Finance (MoF); Ministry of Housing and Public Works; Ministry of Industries (MoI); Ministry of Power, Energy and Mineral Resources; ; National Board of Revenue (NBR); and Palli Karma-Sahayak Foundation (PKSF).

CHAPTER 10. EXPANDING THE RANGE OF ENVIRONMENTAL MANAGEMENT TOOLS IN BANGLADESH

10.1 Introduction

By making environmental clearance its predominant environmental management tool and focusing on command-and-control, Bangladesh has not taken sufficient advantage of more flexible and effective policy instruments to address its environmental priorities.

10.2 Types of environmental policy instruments

Available environmental policy instruments can be categorized depending on the level of government involvement needed for their implementation. At one extreme, such instruments include fines or sanctions that are linked to traditional command-and-control (CAC) regulations. According to Giner (2012), CAC regulations focus on preventing environmental problems by mandating standards and technologies to control pollution. This approach generally relies on emissions standards, ambient standards, and technology-based and performance-based standards in conjunction with enforcement programs. At the other extreme, they include laissez-faire approaches that require consumer advocacy or private litigation to act as incentives for improving environmental management. In between are the more familiar tax-and-subsidy approaches, as well as the less familiar mechanisms relying on traded property rights (Sánchez-Triana et al. 2020). Table 10.1 illustrates the broad spectrum of instruments that might be available, all of which implicitly or explicitly have some incentive effect.

Currently, the ECA, ECR and APCR only consider control-oriented mechanisms. ECC is used as a tool to manage the environmental impacts of specific projects rather than to establish an analytical and participatory effort to incorporate the environmental and social concerns of different stakeholders into the decision-making of authorities. By focusing on the environmental impacts of specific projects, ECC has become a "de facto substitute" for the lack of, and weak enforcement of pollution control regulations and effective land-use planning. The inclusion of design and operation conditions as part of the ECC is akin to tailoring CAC regulations to the specific characteristics of a proposed project.

ECA and ECR only contemplate the preparation of IIEs and EIAs for projects, primarily industrial and infrastructure developments. A first gap in Bangladesh's institutional framework is therefore the absence of instruments to assess the environmental implications of policies, which can have a significant influence on the types of projects that are developed later to achieve policy goals. As recommended in chapter 4, the GoB might consider establishing the use of SEAs to assess the social and environmental effects of policies, building on the experiences of other countries, such as Laos and Pakistan (Sánchez-Triana, Enriquez, and Afzal 2014; World Bank 2019). Policy-based Strategic Environmental Assessments (SEAs) can be used to (a) identify environmental priorities for poverty alleviation and analyze the capacity of natural resources and environmental services to support sector-wide economic activities and sector growth; (b) highlight institutional and governance gaps or constraints affecting environmental and social sustainability; (c) promote capacity building and institutional, legal, and regulatory adjustments critical for environmental and social sustainability of sector reforms; (d) strengthen accountability on the management of environmental and social risks through increasing transparency and empowering weaker stakeholders; and (e) institutionalize social learning processes around the design and implementation of public policies (World Bank et al. 2011).

Table 10.1. Classification of environmental policy instruments based on flexibility in individual decision-making

MINIMUM FLEXIBILITY				MAXIMUM FLEXIBILITY
Greater government involvement				Greater private initiative
Control oriented	Market-oriented			Litigation-oriented
Regulations and sanctions	Charges, taxes, and fees	Market creation	Final demand intervention	Liability legislation
General examples				
Standards Government restricts nature and the amount of pollution or resource use for individual polluters or resource users. Compliance is monitored and sanctions imposed (fines, closure, and jail terms) for noncompliance.	**Effluent or user charges:** Government charges fees to individual polluters or resource users based on amount of pollution or resource use and nature of receiving medium. The fee is high enough to create an incentive to reduce impacts. **Subsidies:** Government provides subsidized inputs to encourage their adoption.	**Tradable permits:** Government establishes a system of tradable permits for pollution or resource use, auctions or distributes permits, and monitors compliance. Polluters or resource users trade permits at unregulated market prices.	**Performance rating:** Government supports labeling/performance rating program that requires disclosure of environmental information on the final end-use product. Performance based on adoption of ISO 14000 voluntary guidelines: zero pollution discharge, mitigation plans submitted; pollution prevention technology adopted, reuse policies and waste recycling.	**Strict liability legislation:** The polluter or resource user is required by law to pay any damages to those affected. Damaged parties collect settlements through litigation and the court system.
Specific examples for Bangladesh, including instruments proposed under the Environmental Fiscal Reform				
• Pollution standards (standards for water discharges included in the ECR). • Licensing of economic activities (ECC). • Land use restrictions or zoning requirements (location clearances). • Bans applied to specific types of waste (prohibition of polythene shopping bags).	• Noncompliance pollution charges (proposed charges for illegal dumping of household waste). • Pollution charges (proposed taxes on air pollution emissions). • Source-based effluent charges to reduce downstream water treatment requirements (proposed taxes on industrial effluents). • Royalties and financial compensation for natural resources exploitation (proposed timber extraction taxes). • Subsidies to construct Common Effluent Treatment Plants (government-funded industrial parks with CETPs).	• Payment of ecosystem services to forest owners to ensure water protection ecosystem services. • Designation of property rights to farmers to improve irrigation water and drainage management. • Deposit-refund systems for solid and hazardous wastes, including ULAB. • Tradable permits for water abstraction rights, and water and air pollution emissions.	• Consumer product labeling (eco-labels) relating to production practices, energy efficiency, and so forth. • Supply chain intervention where intermediate buyers insist on installation of Effluent Treatment Plants for upstream product production processes. • Education regarding recycling and reuse. • Disclosure legislation requiring manufacturers to publish solid, liquid, and toxic waste generation. • Blacklisting of polluters.	• Damages compensation to plaintiffs. • Liability placed on guilty firm's managers and environmental authorities. • Long-term performance bonds posted for potential or uncertain hazards from infrastructure construction. • "Zero net impact" requirements for infrastructure projects.

Source: Sánchez-Triana et al. 2020.

The 8FYP mentions a future Environmental Fiscal Reform (EFR), including mainstreaming environment and climate change in planning and budgeting; creating a special fund for environmental conservation areas; adopting pollution charges; phasing out fossil fuels subsidies; setting pricing policies for water, sanitation, and solid waste management, among others. The fiscal reform would also comprise mechanisms to mobilize private finance, potential including through pricing, legal, and regulatory instruments, and co-financing through Public-Private Partnerships (General Economics Division 2020). Such an EFR would help the GoB expand the range of environmental management tools and potentially, to move away from the current emphasis on ECC and permit-based regulations. The GoB can benefit from substantial experience from developing and developed countries in implementing alternative environmental management instruments, including lessons about the institutional capabilities needed to implement them. While the EFR is not approved yet, the most efficient instrument has been international markets standards required by purchasers of Bangladesh export goods, such as textiles and garments.

10.3 Market-oriented options

10.3.1 Charges, taxes, and fees

A potential advantage of market-oriented instruments, such as charges, taxes, and fees, for environmental management in developing countries is that these are generally designed and implemented by fiscal authorities, which tend to have relatively strong institutional capabilities. Emission or effluent charges are applied to emissions that are released into the air, water or soil and are most suited for large stationary sources. They can be levied on emissions that are directly metered, on a proxy source (for instance, water consumption can be used as a proxy for wastewater emissions), a presumptive pollution level or in the form of a flat rate (The World Bank Group; United Nations Environment Programme; United Nations Industrial Development Organization, 1999). Given the lack of widespread monitoring in Bangladesh, a presumptive pollution level might be considered. Under this approach, a firm is compelled to pay the charge with no specific monitoring conducted, based on an international benchmark or available in-country data. If the firm wishes to reduce its tax burden, it must conduct monitoring at its own expense (but still subject to regulatory audit) to demonstrate that its actual pollution loads are less than the presumed loads.

Another critical consideration in designing the taxes is ensuring that they target the specific pollutant that is causing the most significant effects. A common, but inefficient practice, has been to adopt taxes for water pollutants such as Biological Oxygen Demand or Total Suspended Solids. Taxing these pollutants is convenient because their discharges are measured and can become a significant source of tax revenues. However, it would be more efficient to tax pollutants that are known to cause the most significant environmental health risks, such as hazardous waste and chemicals.

Similarly, the GoB might consider taxing the sources of air pollutants that are associated with the most significant health effects, considering higher rates for the most harmful emissions such as from coal-fired power plants and diesel vehicles (Thurston et al. 2021). Given that many of leading air pollutants also contribute to climate change and are emitted from the same sources, there might be opportunities to tax these same sources through carbon taxes, thereby building synergies between air quality management and climate change mitigation (chapters 6 and 7). Following this approach, the World Bank has helped client countries, including in the metropolitan area of Medellin, Colombia, to design taxes targeting primary and secondary $PM_{2.5}$ from mobile and stationary sources. In Bangladesh the GoB could, for example, consider a carbon tax focused on the energy sector to be implemented progressively. This additional carbon tax would be introduced in the fuel tax system, requiring only limited administrative capacity with little scope for noncompliance (World Bank 2022). Additionally, the GoB should consider a policy reform to earmark part of the revenue generated from pollution charges to finance environmental and health activities.

Before fixing the tax rate, governments need to carefully analyze the country's economic, social, and political context. If not correctly designed and implemented, pollution taxes may sometimes cause undesired effects or disproportionately affect low-income groups (Partnership for Market Readiness 2017). To prevent these cases from happening, the GoB should consider conducing economic and distributional modeling to predicting potential leakage or distributional impacts and mitigation measures. As the GoB moves forward with the transition from subsidizing to taxing fossil fuels indicated in the 8FYP and other component of the EFR, it might consider using quantitative and qualitative methods to assess their effects on lower income households, as well as assessing the capacity of existing safety nets to protect the poor and vulnerable from potential shocks (chapter 7). For more specific guidance on how these assessments may be conducted, see the Energy Subsidy Reform Assessment Framework developed by the World Bank's Energy Sector Management Assistance Program (see https://esmap.org/esraf). For example, this type of policy could be accompanied by income redistribution and other measures to avoid potential increase in the use of solid fuels by poor households, as a result of increased prices of LPG.

10.3.2 Deposit-refund systems

Deposit-refund systems are another potentially relevant environmental policy instrument that has not been mentioned as part of the EFR under 8FYP. In such system, regulators impose a monetary sum that is paid when a product is purchased. This deposit is refunded when the item or its packaging is returned for recycling or appropriate disposal. This model has advantages over taxes that are applied directly to waste and has been successfully implemented in many countries, being a potential instrument for plastic waste management (chapter 8). A deposit-refund system can be effective in coping with some challenges that arise from waste management taxes that are applied directly to households. For instance, households might turn to waste burning or illegal dumping when waste disposal is directly taxed. Conversely, rebates for products that are returned constitute an incentive for appropriate waste management.

In the United States, deposit-refund systems are applied to different products as lead-acid batteries, pesticide containers and tires. The Battery Council International (BCI), recommends retailers to charge a $10 deposit on all batteries sold, the fee is reimbursed when the customer returns the used battery for recycling within 30 to 45 days of purchase. According to the BCI, lead batteries have a recycling rate of 99.3 percent and are the most recycled consumer product in the US. The rate of recycling is attributed to industry investment in a state-of-the-art closed-loop collection and recycling system which keeps more than 129 million lead batteries away from landfills annually (SmithBucklin Statistics Group 2019).

As lead exposure is a major environmental health risk in Bangladesh, the GoB might consider establishing a deposit/refund schemes for the purchase of Lead Acid Batteries (LAB), a major source of lead pollution in Bangladesh (GAHP 2021). Under this policy instrument, a charge would be made on the new battery and returned to the customer when the used battery is returned to a shop that sells LAB for recycling. Another potential tool consists of a battery fee imposed on buyers that is transferred to formal sector recyclers after they demonstrate that they have purchased and safely recycled a Used Lead Acid Battery (ULAB). The additional income received from this fee should increase the amount that formal sector recyclers can pay for ULABs, therefore reducing, and hopefully reverting, the disadvantage that formal collectors face in the market. This tool must be carefully designed to provide the appropriate level of incentive to the formal sector to bid more for ULABs. It should also be carefully administered to ensure that formal sector operators only receive the income from the fee only if they purchase and safely recycle a ULAB (Global Battery Alliance 2020).

10.3.3 Extended Producer Responsibility (EPR)

Extended Producer Responsibility (EPR) refers to a policy that aims to make producers responsible for the environmental impacts of their products throughout the value chain, from the design to the post-consumer phases (OECD 2016). EPR systems have been adopted with the aim of alleviating municipalities' burden for managing waste, reducing the amount of waste destined for final disposal, and increasing rates of recycling – another relevant policy for plastic and hazardous waste management, such as from lead acid batteries (chapters 5 and 8). In addition, by shifting the responsibility upstream toward the producer, EPR systems aim to provide incentives to producers to include environmental considerations in their products' design.

Hilton et al. (2019) identified about 400 EPR systems in operation worldwide, most of them in OECD member countries. Electronics, tires, and packaging are products for which many EPR systems have been adopted worldwide. EPR systems may include a physical responsibility for adequately collecting and treating the waste and/or a financial obligation to pay for such collection and treatment. Bangladesh's Solid Waste Management Rules 2021 include provisions based on the EPR. It will be important to monitor the effectiveness of this approach, and based on that information, assess opportunities to either expand it to other products or identify opportunities to strengthen it.

EPR approaches could also be used to collect LABs at the end of their useful lives. These schemes, (also known as "Producer Take Back") have been implemented in countries such as Brazil and aim at incentivizing manufacturers to create products that are more durable, recyclable, and less toxic and to develop a sales network that recovers the ULAB.

In Brazil, regulations impose on battery manufacturers the responsibility to control and report on all processes involving extraction, utilization, and recovery of lead components. By adopting reverse logistics, retailers were able to collect and send back all ULABs to distributors, and for distributors to divert ULABs to legal smelters appointed by the manufacturers. The regulations helped legal, controlled organizations regain control of the lead reclaiming process, leading to a more upgraded industry and significantly lower environmental impacts.

In 2007, before the regulations were adopted, global secondary production of lead accounted for 54 percent of the refined lead production in Brazil; this share climbed to 70 percent and was projected to reach up to 90 percent by 2020 (Global Battery Alliance 2020). Brazil's "Producer Take Back" regulations were complemented by fiscal reforms that exempted taxes on ULAB cores parts, to discourage sales to the informal sector. This tax exemption contributed to decrease reliance on informal recyclers in the lead battery value chain, without reducing government revenues. As higher volumes of LABs were produced or retailed due to the higher quantity and lower cost of reclaimed lead stimulated by adopted regulations, government's overall tax revenue increased (Global Battery Alliance 2020).

To be successful, such mechanisms must try to avoid creating a financial burden on authorities, except for the relatively small costs associated with monitoring the scheme to ensure that LAB sales, including those in new vehicles, match ULAB recovery (Basel Convention 2004). Manufacturers should anticipate their batteries being recycled and returned to them and should create pathways to allow for this process through reverse logistics (Global Battery Alliance 2020).

10.3.4 Final demand interventions

Final demand interventions provide information to investors, consumers, and the public, and decentralize decision making to the final consumer. These tools can encourage behavioral change of consumers towards long-term sustainability, encouraging producers to adopt more environmentally friendly approaches. One form of final demand intervention involves promulgating disclosure requirements. The GoB might consider establishing public disclosure schemes in key sectors, building on the experiences from other LMICs, such as label systems to raise awareness of companies' environmental performance, and disclosure of pollution charges paid by firms.

The Eco-watch program in the Philippines provided incentives to industries to comply with environmental regulations by setting up an environmental grading, color labeling system to categorize companies' environmental performance. In 1997, before the program came into effect, over 92 percent of plants were found to be noncompliant; by 1998 the number of compliant plants increased to 58 percent (Kathuria 2008). For foreign buyers, the Accord on Fire and Building Safety in Bangladesh provides a good example of engagement with external stakeholders that could be adapted for environmental compliance. In 2013, this legally binding Global Framework Agreement was signed by global brands, retailers, and trade unions to improve safety and health conditions in the Bangladeshi Ready-Made Garment (RMG) industry.

In Colombia, the Cauca Valley Corporation adopted a water pollution charge program. The effluent fees paid by firms were publicly disclosed and the publicity influenced the reputation and decisions of company leaders reducing the discharge of water pollutants (Sánchez-Triana and Ortolano 2005). Korea's CleanSYS monitors the air pollutants emitted from stacks in real time using an automatic stack measuring device that connects online to control centers at the Korea Environment Corporation (K-eco). This information is then used to enforce regulations, inform new policy measures, and shared with public agencies for purposes of financial decision-making, including for credit application from the private sector. As the system is based on automated telemonitoring devices, it reduces administrative burden and enable early warning and real time public disclosure of measurements[85].

While labels convey a signal of how environmentally friendly a product is, disclosure requirements provide information on the environmental performance of a firm, including emissions to air, wastewater discharges, waste, and compliance with standards. There are no sanctions attached to such disclosure, but it gives investors and consumers a better-informed choice among multiple goods, services and investments.

10.4. Litigation-oriented options: Liability legislation

Liability for environmental harm is designed to compensate affected individuals or groups, with a particular focus on restoring or replacing damaged resources and/or compensating lost value (Jones et al. 2015). Litigation-oriented approaches to environmental management require only that legislation be in place that confers relatively straightforward rights and obligations to resource users. These approaches form a legal umbrella for court cases, which then consider the nature and extent of environmental damages on a case-by-case basis. Advocates of liability legislation argue that it is a highly efficient instrument to address externalities because it only requires monitoring of specific incidents, rather than a need to monitor behavior, as is required by regulation (Shavell 2013).

Common challenges faced in developing countries include difficulties in estimating damages and the required compensation and limited accountability for ensuring that recoveries intended for restoration are spent to that end (Jones et al. 2015). Even in industrial countries, the use of liability legislation is hampered by the analytical difficulties of establishing cause and effect, or of ascribing blame or negligence. In the case of Bangladesh, the priority measures for enhancing the environmental court system are to (a) reform the Environment Court Act, expanding legal standing to all citizens and creating the roles of environmental prosecutors and technical experts, (b) adopt further rules and guidelines for applying the polluter pays principle (for example, criteria for setting the value of fines and imposing more severe penalties), and (c) invest in training for judges and court staff on major environmental issues (chapter 3).

Furthermore, use of the courts to tackle environmental challenges must bring with it the awareness that these mechanisms often discriminate against the poor and others with limited access to legal recourse. To address that, DoE could foster partnerships with the Public Attorney's Office, the Bangladesh Bar Council, law schools and pro bono legal organizations. Disclosing environmental data, such as pollution levels in certain areas and detailed information of enforcement activities performed by DoE, is also essential to inform judicial processes and can be even more important when citizens obtain direct access to environment courts.

10.5 Conclusions and recommendations

As Bangladesh continues to develop its institutional framework for environmental management, it should consider developing a wider range of environmental instruments, including (a) economic and market-based instruments, such as pollution charges, deposit-refund schemes, EPR, and final demand interventions, and (b) litigation-based instruments, including liability legislation. These instruments could initially focus on identified environmental priorities and gradually expand to cover additional areas. In this process, the GoB should carefully assess the interventions' potential economic, social, and distributional effects, as well as identify mitigation measures for those impacts.

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CHAPTER 11. A WAY FORWARD

Over the last decade, Bangladesh has made tangible progress in its policy regime and systems for environmental and pollution management. Yet, much more needs to be done to control environmental degradation and improve the people's health and economic productivity. Based on the country's environmental priorities, the CEA has identified priority interventions to improve environmental quality and accelerate Bangladesh's transition towards green growth. The following recommendations cover policies and investments to (a) enhance environmental governance, especially the institutional capacity of environmental agencies; and (b) control pollution at its sources with interventions in key economic sectors. Table 11.1 summarizes these recommendations, indicating their potential impact and timeline.

11.1 Interventions to address Bangladesh's environmental priorities

The CEA provides policy and investment options to the GoB to address household and outdoor air pollution; improve water, sanitation and hygiene (WASH); reduce exposure to lead; and improve plastic waste management.

Approving a National Air Quality Management Plan (NAQMP) to reach WHO's annual $PM_{2.5}$ Interim Target 1 of 35 µg/m^3 by 2030, coupled with a Heavy Air Pollution Contingency Plan (HAPCP) to reduce emissions and people's suffering during times of extreme pollution, should be a top priority for the GoB. Interventions under those plans should be implemented through a clean air program based on diverse policy instruments. Interventions to reduce ambient $PM_{2.5}$ should include (a) eliminating the burning of solid waste, coupled with the separation of food waste and its collection and centralized composting in urban and rural areas; (b) improving the management of agricultural fertilizers and livestock manure; (c) controlling emissions from industry and the power sector, including by improving fuel quality; (d) reducing road and construction dust, covering nonmotorized mobility and traffic-management initiatives; (e) modernizing brick kilns and shifting from fired clay bricks to non-fired blocks or other alternative building materials; and (f) replacing the household use of solid fuel for cooking by switching to liquefied petroleum gas (LPG) or electricity. Item (f) is the most effective intervention to improve ambient $PM_{2.5}$, and this step has the added benefit of reducing the health effects of household air pollution. To design the priority measures for controlling household air pollution, the GoB should (a) further assess the potential for promoting the use of electric stoves for cooking, and perhaps especially induction stoves. This is a cheaper option than LPG for small users of electricity that can benefit from lower residential block tariff rates for electricity; and (b) further assess price and non-price obstacles and incentives for adoption of LPG for cooking. In the transition to cleaner fuels for households, the continued expansion of improved cookstoves programs (particularly promotion of dual-burner stoves) will continue to be important for households that cannot afford cooking with LPG or electricity.

A comprehensive program must include a portfolio of measures that deliver sufficient air quality improvements, while also being economically, socially, administratively, and politically acceptable. In parallel, health policies are needed to (a) enhance curative care of health problems brought on by air pollution; and (b) gather community-level data on the health issues in air pollution hotspots, coupled with meteorological and air quality data, to inform policy decision-making. Because of transboundary emissions, cooperation across Bangladesh districts and with countries of the Indo-Gangetic Plain is indispensable for achieving substantial air quality improvements. At the same time, regionally harmonized strategies could alleviate the need to take the most expensive measures.

To address the challenges of lead pollution and population exposure, which will still take time to solve, the GoB should prioritize undertaking representative BLL measurement studies along with identifying sources of lead exposure. These data will inform further policy formulation. In the meantime, to mitigate the impacts of lead exposure, the GoB may consider provisional interventions to (a) supplement iron for children ages 6 to 59 months; (b) replace lead contaminated cookware made from recycled aluminum; and (c) rehabilitate abandoned used lead-acid battery (ULAB) recycling sites. The main benefit of these interventions is increased lifetime income from averting IQ losses in early childhood. Additionally, immediate action can be taken to (d) build the country's laboratory capacity for measuring BLL and testing lead in food and other products; and (e) enhancing coordination across environmental, health, food safety and consumers agencies to improve data management, policy formulation and awareness of lead poisoning and prevention measures among key stakeholders such as health providers and community leaders.

To improve WASH, the interventions with the highest benefit-cost ratios for addressing microbiological pollution that should be prioritized are (a) household point-of-use treatment of drinking water with ceramic filter; (b) safely managed improved non-shared sanitation for households currently having unimproved sanitation; and (c) promotion of handwashing with soap targeting caregivers of children under five. Further measures that should follow are (a) safely managed improved non-shared sanitation for households currently sharing sanitation with other households; and (b) promotion of handwashing with soap to all household members. For mitigating exposure to arsenic in drinking water, three control interventions should be prioritized: provision of deep tube wells; ponds with sand filter; and household filtering, such as SONO filter that uses iron and sand filtration. Investing in a comprehensive program for water resources management, as envisaged in the Bangladesh Delta Plan 2100, could be highly beneficial not only to improve WASH, but also to mobilize local labor and other unemployed resources. In the short-term, further analysis on water pollution is needed to (a) assess the impacts of other highly poisonous heavy metals in both drinking water and rivers, such as lead, mercury, and cadmium, (b) assess the impacts of and potential solutions for salinity intrusion; and (c) identify specific interventions to manage industrial effluent or liquid discharge as well as untreated municipal sewage water.

For improving plastic waste management, the GoB should adopt a holistic integrated approach based on a combination of legal, financial, and communication instruments. Recommended measures include (a) research and development of alternatives to single-use plastics; (b) effective implementation of the ban on plastic bags and extending its scope to other single-use plastic items; (c) mandatory Extended Producer Responsibility (EPR) guidelines to enable industry co-funding of plastic-waste collection and recycling systems and establish producer responsibility organizations (PROs); (d) an integrated waste management framework to address growing plastic waste and disposal in open places; (e) waste segregation at the household level, developing the missing infrastructure, and conducting behavior-change campaigns; (f) harmonization of plastic-management policies to promote circular economy; (g) plastic cleanup and recovery schemes to reduce legacy plastic waste and mitigate associated impacts; and (h) a monitoring system for the implementation of the Solid Waste Management Rules 2021 and targets of the Plastic Action Plan.

11.2 Strengthening environmental governance systems

To design and implement the pollution management interventions, the GoB also needs to overcome shortcomings in its environmental governance framework. Additional measures are needed to inform policy and decision-making with reliable data; expand the range of environmental policy instruments beyond command-and-control; improve the organizational structure and institutional capacity of the MoEFCC and DoE, as well as their coordination with line agencies and local governments; fulfill environmental justice and promote citizen-driven accountability; and enable the environment for green financing.

11.2.1 Setting evidence-based priorities and decision-making.

Bangladesh's environmental governance system shows a misalignment between the country's environmental priorities—such as air and water quality, control of lead and other hazardous chemicals—and its organizational structure, efforts, and resource allocation. This is largely due to (a) the absence of an integrated system of reliable data collection, management, and dissemination, and the absence of organizational capabilities to provide analytical support to the decision-making process; (b) the lack of representation of vulnerable groups that are mainly affected by environmental degradation; and (c) the absence of a formal planning mechanism for allocating financial and human resources according to clearly defined environmental priorities that are linked to poverty alleviation and social priorities.

To address those challenges, the GoB needs to enhance its environmental monitoring and data management capacity, including systematic evaluation of government interventions, automated air and water quality monitoring networks, outcome-oriented indicators to assess institutional performance, and adequate institutional presence in the field with sufficient and well-trained staff. Another key measure is the creation of a research and development unit at the DoE. This unit would conduct the analytical work in partnership with other government agencies and development partners to identify priorities and inform environmental planning—for example, through estimates of the cost of environmental degradation, cost-benefit analyses, and economic and distributional modelling.

11.2.2 Diversifying and strengthening environmental policy instruments

As Bangladesh continues to develop its legal and institutional framework for environmental management, it should consider developing a wider range of environmental instruments, including (a) economic and market-based instruments such as pollution charges, deposit-refund schemes, EPR, and final demand interventions; (b) litigation-based instruments, including liability legislation; and (c) information-based instruments, such as awareness campaigns on the health effects of pollution and measures to improve hygiene, and regular dissemination of environmental quality data and pollution loads, such as user-friendly alert systems on air quality and pollution hotspots, publication of lists of highly polluting industries, and detailed results of enforcement activities. In designing the new policy instruments and associated investments, the GoB should carefully assess the interventions' potential economic, social, and distributional effects, as well as identify mitigation measures for those impacts.

These policy instruments could initially focus on identified environmental priorities, such as through a carbon tax and incentives for household use of cleaner fuels for cooking, and gradually expand to cover additional areas. As indicated by the experiments of the CGE Bangladesh Bioeconomic 101 model, the phaseout of existing energy subsidies may be a first choice for a fiscal policy intervention, with beneficial effects on both efficiency and environmental protection, especially for air quality. Its impact on inclusiveness would also be beneficial if the policy were to be combined with a redistribution of government savings to the poor. Setting the stage for efficient carbon markets also appears to be a feasible policy for Bangladesh with several beneficial effects, especially if combined with suitable policies for redistribution to poorer households. Additionally, these policy options may be reasonably effective in generating benefits (reduction of externalities), increasing GDP, and improving the condition of the poor. However, a combination of policy measures seems more effective than isolated interventions. In addition, command-and-control policies can be usefully complemented by fiscal and redistribution measures. Furthermore, compared to GDP, net social benefits tend to grow more than proportionally with policy combinations—and even more so if these policies include redistributive policies.

As for command-and-control, a comprehensive amendment to the Environment Conservation Act and its rules is needed to (a) modernize and make enforcement activities more efficient, including clear provisions to implement the polluter pays principle and set adequate sanctions and incentives for compliance with the ECA provisions; (b) set the mandates and foundations for further regulations on EPR and Payment for Ecosystem Services (PES); (c) mobilize green financing by establishing a permanent environmental fund, which could receive resources from the compensation for environmental damage envisaged in Article 7 of ECA and eventually from environmental taxes; (d) improve stakeholder engagement in environmental decision-making; (e) require Strategic Environmental Assessment for policies, plans, and programs to be further regulated through specific rules, among other themes.

Such as a diverse, economically efficient policy and regulatory framework is essential to increase the effectiveness of environmental clearance system, especially to improve decision-making. As a first measure, the DoE should conduct an in-depth, independent evaluation of ECCs approved for red and orange category projects, to extract common challenges and lessons to inform policy formulation—not only for improving the EC process, but also further regulate specific technical requirements. The GoB should amend the ECA or adopt a specific act to require SEAs for policies, programs, and plans, and establish the mandates and procedures for those assessments. Although the ECR 2023 is expected to improve the EC process, additional amendments and guidelines are required to clarify and strengthen assessment criteria and procedures related to key themes – for example, the screening of projects that are not pre-categorized in the ECR; monitoring and enforcement after ECC issuance; stakeholder consultations and access to information, including through ICT tools.

11.2.3 Strengthening organizational structure and institutional capacity

The GoB should carry out a detailed analysis of the organizational structure under the MoEFCC and affiliated agencies to set clearer mandates and more efficient processes for environmental governance, including interagency coordination. The DoE needs specialized technical units to respond to identified environmental priorities with the necessary human, technical, and financial resources to fulfill their mandates. Rising the DoE's budget is essential to strengthen its capacity to execute decisions, especially for monitoring and enforcement activities. The GoB could consider a policy reform to earmark part of the revenues generated from fines and pollution charges to finance environmental activities, such as those expected from the proposed EF. Additionally, establishing a cadre of environmental specialists and increasing DoE's headcount will allow more qualified professionals to reach senior official positions, attract and retain talented individuals, and ensure that decisions and policies are made by people with adequate background and experience. Completing the DoE's decentralization process is also essential to expand its physical presence to all districts, with adequate staffing, equipment, and budget, and to expedite actions and better balance the needs and priorities of central government officials and politicians with local stakeholders. For that, a comprehensive information management system with automated monitoring for compliance and enforcement is essential for an effective decentralization process, as well as for gathering critical data to inform decision-making and public participation.

11.2.4 Strengthening environmental justice and citizen-driven accountability.

Responding to priority environmental challenges in Bangladesh calls for a more systematic effort to raise awareness and social accountability regarding environmental issues. Also missing in the current institutional framework are mechanisms to incorporate the concerns of groups most severely affected by environmental degradation into the GoB's planning processes, as well as to allow citizens to directly litigate in environmental courts as plaintiffs. Ways to improve public information and promote transparency, accountability, and awareness include the publication of data in support of key environmental indicators (including pollution loads and environmental health statistics); wider use of public forums to air development initiatives; and broader and more detailed review and discussion of environmental management tools. Mechanisms to disseminate information in a manner that is easily interpretable can allow communities to serve as informal regulators.

To improve the environment court system, the GoB should proceed with a comprehensive reform of the Environment Court Act, expanding legal standing to all citizens and creating the roles of environmental prosecutors and technical experts. An environmental prosecution agency that is independent from the DoE and shielded from political interference could make the environmental courts system more effective. Additionally, the DoE could promote partnerships with the Public Attorney's Office, the Bangladesh Bar Council, law schools, and pro bono legal organizations to support those citizens with limited access to legal recourse.

Additional rules and guidelines are needed for applying the polluter pays principle effectively, including for example, criteria for setting the value of fines, precautionary measures, and more severe penalties such as confiscation of equipment, suspension of construction and productive activities, and payment of daily fine for not complying with court orders. Judges and court staff should be regularly trained on major environmental issues, especially those that are subject to the highest number of judicial cases (for example, illegal brick kilns). Disclosing environmental data, such as pollution levels in certain areas and detailed information of enforcement activities performed by the DoE, is also essential to inform judicial processes and can be even more important when citizens obtain direct access to environment courts.

11.2.5 Building an enabling environment for green financing

To facilitate the flow of resources from green finance suppliers to sectors pursuing these resources, the GoB should create an environmental management ecosystem by (a) adopting a broad-based national green growth strategy and a national action plan backed by a commensurate set of regulatory and institutional frameworks, (b) constituting a high-level national oversight body to coordinate and monitor the progress of green growth efforts, and (c) creating an ecosystem of ministries and government agencies that collect and analyze point-source data to enforce policies that create a pipeline of verified investment-ready projects.

In expanding its range of environmental policy instruments, the GoB should use a mix of incentives to boost environmental markets by (a) encouraging the adoption of green practices and promoting green businesses and investments with positive environmental externalities, (b) adopting incentives that address the risks faced by FIs, (c) fostering a collaborative institutional system to implement green financial incentives, and (d) reducing the risks perceived by financiers and boosting private-sector adoption of green practices and technologies, and thereby boosting the offering of green products and services. It is also essential to strengthen institutional and borrower capabilities by building skills and expertise on green financing across sectors, from technocrats in government agencies to FIs, and from private businesses to students.

Table 11.1 Summary of CEA recommendations

Type [a]	Action	Implementation period		
		Immediate priority	Short-term (2024–25)	Medium-term (2026–30)
Pillar A. Addressing Bangladesh's environmental priorities				
A.1 Improving ambient and household air quality (chapters 2, 5, 6, and 7)				
	Adopt a National Air Quality Management Plan (NAQMP) based on diverse policy instruments, including measures to address both ambient and household air pollution.	•		
	Adopt a Heavy Air Pollution Contingency Plan (HAPCP) to reduce emissions and people's suffering during times of extreme pollution, including requirements and procedures for triggering a graded set of restrictions.	•		
	Promote use of clean energy in cooking, switching from solid fuel use to liquefied petroleum gas (LPG) or electricity.	•	•	•
	Further assess (a) the potential for promoting the use of electric stoves for cooking, and (b) price and non-price obstacles and incentives for adoption of LPG for cooking.	•		
	Control emissions from industry and the power sector including stricter emission standards for coal and furnace oil-fired power plants; mandate the installation of emission control devices on smokestacks; invest in renewables for electricity generation; restrict the installation of future coal-fired powerplants; and provide incentives, subsidies, and tax breaks to manufacturers who invest in clean technologies.	•	•	•
	Improve quality of fuels (especially with low-sulfur diesel), enforce traffic control and effective management systems; enforce vehicle emissions inspections; restrict high-emission vehicles from roads (including heavy-duty vehicles); optimize urban layout strategies to prioritize sustainable transportation modes; and incentivize mass, nonmotorized, and electric mobility.	•	•	•
	Improve fertilizers and livestock-manure management to control ammonia emissions.	•	•	•
	Reduce emissions from waste through integrated solid waste management (see item A.4 below).	•	•	•
	Reduce road and construction dust, including investments in paving and street-washing practices.	•	•	•
	Modernize brick kilns and promote use of non-fired bricks.	•	•	•
	Set the stage for carbon markets, including MRV systems, and adopt fiscal instruments to address air pollution, such as the phaseout of energy subsidies and a carbon tax, combined with redistribution measures to the poor.	•	•	
	Conduct and regularly update emissions inventories and source apportionments, combined with other relevant analytics and data management (see items B.1 and B.4 below).	•	•	•
	Collaborate with neighboring countries to address transboundary air pollution, especially $PM_{2.5}$ emissions.	•	•	•

Type [a]	Action	Implementation period		
		Immediate priority	Short-term (2024–25)	Medium-term (2026–30)
A.2 Reducing exposure to lead (Pb) and other heavy metals (chapters 2 and 5)				
	Adopt temporary measures to reduce exposure to Pb: (a) supplement iron for children from 6 to 59 months, (b) replace Pb contaminated cookware made from recycled aluminum, and (c) rehabilitate abandoned used lead-acid battery (ULAB) recycling sites.	•	•	
	Build the country's laboratory capacity for measuring BLL and testing Pb in food and other products.	•	•	
	Undertake representative BLL measurement studies along with identification of sources of Pb exposure in households, communities, schools, and specific sources, to inform further policy formulation.	•	•	
	Improve analytical base on the impacts, sources, and measures to control other heavy metals (especially mercury and cadmium).		•	
	Adopt additional policies and investments to reduce exposure to heavy metals based on further analysis of its major sources and hotspots.		•	•
	Enhance coordination across environmental, health, food safety, and consumer agencies to improve data management, policy formulation, and awareness of lead poisoning and prevention measures among key stakeholders such as health providers and community leaders.	•	•	•
A.3 Improving drinking water, sanitation, and hygiene (chapters 2, 5, 6, and 7)				
	Prioritize (a) household point-of-use treatment of drinking water with ceramic filter, (b) safely managed improved non-shared sanitation for households currently having unimproved sanitation, and (c) promotion of handwashing with soap targeting caregivers of children under five.	•	•	•
	Complement these measures with (a) safely managed improved non-shared sanitation for households currently sharing sanitation with other households, and (b) promotion of handwashing with soap to all household members.		•	•
	Mitigate exposure to arsenic in drinking water through deep tube wells, ponds with sand filter, and household filtering.	•	•	•
	Implement priority projects of the Bangladesh Delta Plan for water supply and water resources management.	•	•	•
	Improve analytical base on the impacts of and potential solutions for salinity intrusion and identify specific interventions to manage industrial effluent or liquid discharge as well as untreated municipal sewage water.		•	
A.4 Addressing plastic pollution (chapter 8)				
	Promote research and development of alternatives to single-use plastics (SUPs).	•	•	
	Implement the ban on plastic bags and extend its scope to other SUP items.	•	•	
	Adopt mandatory extended producer responsibility (EPR) guidelines for plastic-waste collection and recycling.	•		

Type [a]	Action	Implementation period		
		Immediate priority	Short-term (2024–25)	Medium-term (2026–30)
	Adopt a framework for integrated waste management including waste segregation at the household level, infrastructure development, behavior-change campaigns, stricter requirements for waste incineration, and improved landfill site management practices.		•	•
	Harmonize plastic-management policies to promote circular economy.		•	
	Implement plastic cleanup and recovery schemes to reduce legacy plastic waste and mitigate associated impacts.		•	•
	Establish a monitoring system for the implementation of the Solid Waste Management Rules 2021 and targets of the Plastic Action Plan.	•		
	Pillar B. Strengthening environmental governance systems			
	B.1 Setting evidence-based priorities and decision-making (chapter 3)			
	Enhance environmental monitoring and data management capacity, including automated air and water quality monitoring networks, and adequate institutional presence in the field with sufficient and well-trained staff.	•	•	•
	Create a research and development unit at DoE.		•	
	Implement systematic evaluations of government's interventions and outcome-oriented indicators to assess institutional performance of environmental agencies.		•	
	B.2 Diversifying and strengthening environmental policy instruments (chapters 3, 4, and 10)			
	Adopt economic and market-based instruments, such as pollution charges, deposit-refund schemes, EPR, and final demand interventions.	•	•	
	Adopt litigation-based and information-based instruments, including liability legislation, requirements and procedures for awareness campaigns, and regular dissemination of environmental quality data and pollution loads.		•	•
	Amend or adopt, as applicable, the Environment Conservation Act (ECA), associated rules and guidelines to (a) modernize and make enforcement activities more efficient, based on the polluter pays principle; (b) set the mandates and foundations for further regulations on EPR and Payment for Ecosystem Services (PES); and (c) mobilize green financing through a permanent environment fund, among other themes.		•	•
	Amend or adopt, as applicable, the ECA, associated rules and guidelines to (a) strengthen the environmental clearance system and monitoring of projects after clearance, (b) require Strategic Environmental Assessment for policies, plans, and programs, and (c) improve stakeholder engagement in environmental decision-making.		•	•
	Conduct an in-depth, independent evaluation of effectiveness and efficiency of the environmental clearance system.	•		
	Revise the EIA Guidelines for Industries 2021, updating and expanding their contents as per the ECR 2023, and develop guidelines for non-industry projects.		•	

Type [a]	Action	Implementation period		
		Immediate priority	Short-term (2024–25)	Medium-term (2026–30)
B.3 Strengthening organizational structure and institutional capacity (chapters 3 and 4)				
	Analyze the organizational structure under MoEFCC and affiliated agencies to set clearer mandates and more efficient processes for environmental governance, including interagency coordination.		•	
	Increase DoE's budget and headcount.	•	•	•
	Establish a cadre of environmental specialists for DoE.		•	
	Implement a comprehensive information management system with automated monitoring for compliance, enforcement, and policy formulation.		•	
B.4 Strengthening environmental justice and citizen-driven accountability (chapters 3, 4, and 10)				
	Regularly disclose data in support of key environmental indicators (including pollution loads and environmental health statistics), use public forums to air development initiatives, and conduct broader and more detailed review and discussion of environmental management tools.	•	•	•
	Proceed with a comprehensive reform of Environment Court Act, expanding legal standing to all citizens and creating the roles of environmental prosecutors and technical experts.		•	
	Adopt rules and guidelines for applying the polluter pays principle effectively, including criteria for setting the value of fines, precautionary measures, and more severe penalties.	•	•	
B.5 Building an enabling environment for green financing (chapter 9)				
	Adopt a broad-based national green growth strategy, a national action plan backed by a commensurate set of regulatory and institutional frameworks.	•		
	Create an ecosystem of ministries and government agencies that collect and analyze point-source data to enforce policies and create a pipeline of verified investment-ready projects.	•	•	•
	Adopt incentives to boost environmental markets, such as promotion of (a) green practices, green businesses, and investments with positive environmental externalities; and (b) incentives to address the risks faced by FIs or perceived by financiers; and (c) a collaborative institutional system to implement green financial incentives.		•	•
	Strengthen institutional and borrower capabilities by building skills and expertise on green financing across sectors.		•	•

Source: World Bank.
Note: [a] The meanings of the icons in the left-most column are presented below.

	Policies and institutions		**Investments**		**Analytics and technical assistance**		**Coordination and stakeholder engagement**

APPENDIXES

Appendix A. Data and Methodology for Estimating Health Effects

Estimating the health effects from the major environmental risk factors in Bangladesh requires a large amount of data. This involves establishing (a) the percent of the population exposed to each risk factor or type of pollutant, and (b) the level of pollution to which the population is exposed. A summary of these data is presented in tables A.1a–b and is further discussed in chapter 2.

Nationwide population-weighted ambient $PM_{2.5}$ air pollution is estimated based on a combination of air-quality modeling and ground-level monitoring. Some of the data on the percent of the population exposed to a risk factor or pollution are from the Bangladesh Population and Housing Census 2022 and annual nationally representative household surveys by the Bangladesh Bureau of Statistics (BBS 2019; 2021; 2022) (see tables A.1a and A.1b.) The population exposed to a risk factor or pollution includes the population using solid fuels as primary cooking fuel and thus exposed to $PM_{2.5}$ household air pollution; the population with various types of drinking-water supply and sanitation; and the percent of the population with arsenic in their drinking water as well as arsenic concentration levels. Two measurement studies of $PM_{2.5}$ personal exposure from Bangladesh were used to assess the level of $PM_{2.5}$ household air pollution in households using solid fuels. For exposure to lead (Pb), the data are from blood lead level (BLL) measurement studies of children and adults in various locations in Bangladesh. These studies were conducted during 2000 to 2015. Therefore, a trend analysis was undertaken to estimate BLLs in 2019.

Table A.1a Data on population exposure to pollution in Bangladesh

	Environmental health risk factor	Exposure indicator	Year(s)	Average exposure level	Data sources
1	$PM_{2.5}$ ambient air pollution (AAP)	Population-weighted ambient $PM_{2.5}$	2019–21	64 ug/m³	Estimated from DoE's Monthly Air Quality Monitoring Reports (16 monitoring stations; see DoE (2021) and GBD (2019) ambient exposure estimates
2	$PM_{2.5}$ household air pollution (HAP)	% of population groups using solid fuels as primary cooking fuel: • Rural population • Urban population • National population	2022	 90% 42% 74%	Trend analysis of data from Bangladesh annual SVRS reports (BBS 2019; 2021) and Population and Housing Census 2011 and 2022 (BBS 2015; 2022)
		Household member average personal $PM_{2.5}$ exposure from household use of solid fuels (net of ambient $PM_{2.5}$)	2022	76 ug/m³	Shahriar et al. (2021) and Berkeley Air Monitoring Group (2022) measurement studies in Bangladesh
3a	Lead (Pb) exposure	Lead concentration in blood (BLL) in children and adults	2019	6.4 ug/dL	Trend analysis of nine BLL measurement studies of children and five BLL studies of adults in Bangladesh.
3b	Lead (Pb) exposure at "hot spots"	a) Workers at 15 used lead-acid battery (ULAB) recycling and recharging facilities in Dhaka		65 ug/dL	Ahmad et al. (2014)
		b) Jewelry makers in Dhaka (and workers in associated "back offices")	2015	69 ug/dL (16 ug/dL)	Mazumdar, Goswami, and Ali (2017)
		c) Children living near abandoned ULAB recycling sites		23 ug/dL	Chowdhury et al. (2021); McCartor and Nash (2018)

Source: World Bank.

Table A.1b Data on population exposure to pollution in Bangladesh

	Environmental health risk factor	Exposure indicator	Year	Average exposure level (%)	Data sources
4	Arsenic in drinking water	**Population with:** Arsenic above WHO guideline (10 ppb)	2019	17	Bangladesh MICS 2019 (BBS/UNICEF 2019)
		Arsenic above Bangladeshi standard (50 ppb)	2019	11	
5	Household drinking water, sanitation, and hygiene (microbiological pollution)	**Population with:** Improved drinking water source	2019	99	Bangladesh MICS 2019 (BBS/UNICEF 2019)
		E. coli in drinking-water source	2019	40	
		E. coli in actual drinking water	2019	82	
		Safely managed drinking water (source water)	2019	48	
		Point-of-use treatment (POUT) of drinking water	2019	10	
		Access to improved sanitation facility	2019	85	
		Shared sanitation facility with other households	2019	20	
		Access to improved non-shared sanitation facility	2019	65	
		Access to handwashing facility with water and soap	2019	75	

Source: World Bank.

The data on population exposure to environmental risk factors or pollution are applied in models that specify the relationship between various exposure levels and health effects. The models applied here to Bangladesh are from well-established methodologies used globally to estimate health effects. In most cases, the models are based on studies of health effects that were conducted in a wide range of countries and regions. This includes the health effects of ambient $PM_{2.5}$; household $PM_{2.5}$ air pollution; children's lead exposure; and inadequate drinking water, sanitation, and hygiene. Regarding the effects of lead exposure on adult health, four large studies from the United States were applied. In the case of arsenic's health effects, two studies of mortality from Bangladesh were applied. A summary of the models and methodologies is presented in table A.2. They are further discussed in chapter 2 as well as in appendixes B–J.

Table A.2 Methodologies for estimating health effects of exposure to major environmental health risk factors

	Environmental health risk factor	Health-effect assessment methodology	Elevated exposure levels	Source of methodology
1	$PM_{2.5}$ ambient air pollution (AAP)	Increased risk of morbidity and mortality (heart disease, stroke, COPD, lung cancer, ALRI, type 2 diabetes)	$PM_{2.5}$ > 5 ug/m^3	Global Burden of Disease (GBD) 2019 based on global studies
2	$PM_{2.5}$ household air pollution (HAP)			
3	Lead (Pb) exposure	IQ losses in children	BLL > 0 ug/dL	Analysis of global studies (Crump et al. 2013)
		Increased risk of cardiovascular disease (CVD) mortality among adults	BLL > 0 ug/dL	Review of studies in the US (Brown et al. 2020)
4	Arsenic in drinking water	Increased risk of mortality	As > 10 ppb	Argos et al. (2010) and Sohel et al. (2009) studies in Bangladesh

	Environmental health risk factor	Health-effect assessment methodology	Elevated exposure levels	Source of methodology
5	Household drinking water, sanitation, and hygiene (microbiological pollution)	Risk of illness and mortality for each type of drinking-water source, type of sanitation facility, and lack of access to handwashing facility	Lack of safe services	Meta-analyses of worldwide studies GBD 2019 and Wolf et al. (2014; 2018)

Source: World Bank.

The health effects estimated in this report have a cost to society. The health effects are of three types: (a) Premature mortality from exposure to pollution; (b) Illness from exposure to pollution; and (c) IQ losses among children exposed to lead. There are two main approaches to estimating the cost of these health effects: (a) productivity cost and (b) welfare cost.

The productivity cost measures the effect of ill health or premature mortality on economic output. Ill health causes absenteeism from work and reduced productivity while at work. Ill health also involves medical treatment cost. Premature mortality causes a loss in future income if the individual is economically active. The cost of IQ losses in children is estimated in terms of lower lifetime income.

Productivity cost captures only a portion of the cost of health effects to society. Ill health not only has productivity effects but also involves pain, discomfort, and loss of leisure time. Premature mortality involves complete loss of remaining years of normal life expectancy and not only income. The welfare cost approach was therefore developed to better capture the value that society places on good health and a long life. The welfare cost is usually substantially larger than the productivity cost.

The welfare-cost approach to premature mortality involves estimating the value that society places on avoiding premature mortality. This is accomplished by estimating individuals' willingness-to-pay (WTP) for a reduction in the probability of dying for instance this year. The WTP forms the basis for calculating the so-called value of statistical life (VSL). The VSL is the amount that a group of individuals or society is collectively willing to pay to reduce the risk of mortality to the extent that it saves one life. This is further discussed in appendixes H and I. The welfare approach can also be applied to illness by finding out individuals WTP to avoid or reduce the risk of an episode of illness.

The cost of health effects in this report relies on the welfare-cost approach for mortality and the productivity-cost approach for illness and children's IQ losses (table A.3).

Table A.3 Cost of health effects

	Environmental health risk factor	Method for estimating cost of health effects
1	$PM_{2.5}$ ambient air pollution (AAP)	Mortality: Welfare cost (VSL) Illness: Productivity cost
2	$PM_{2.5}$ household air pollution (HAP)	Mortality: Welfare cost (VSL) Illness: Productivity cost
3	Lead (Pb) exposure	Children's loss of IQ: Productivity cost Adult mortality: Welfare cost (VSL) Adult morbidity: Productivity cost
4	Arsenic in drinking water	Mortality: Welfare cost Illness: Productivity cost
5	Household drinking water, sanitation, and hygiene	Mortality: Welfare cost Illness: Productivity cost

Source: World Bank.

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Appendix B. Health Effects of Particulate Matter Pollution

Particulate matter (PM) is the air pollutant that globally is associated with the largest health effects. It is a major outdoor ambient air pollutant and a major household air pollutant from the burning of solid fuels for cooking and, in cold climates, heating. Health effects of PM exposure include both premature mortality and morbidity. The methodologies to estimate these health effects have evolved as the body of research evidence has increased.

The Global Burden of Disease (GBD) derived an integrated exposure-response (IER) function for health outcomes associated with exposure to $PM_{2.5}$ both in the outdoor ambient and household environments (Burnett et al. 2014; Shin et al. 2013). The health outcomes assessed in the GBD up to 2016 are ischemic heart disease (IHD), cerebrovascular disease (stroke), lung cancer, chronic obstructive pulmonary disease (COPD), and acute lower respiratory infections (ALRI) (GBD 2013 Risk Factors Collaborators 2015; GBD 2015 Risk Factors Collaborators 2016; GBD 2016 Risk Factors Collaborators 2017; Lim et al. 2012; Mehta et al. 2013; Smith et al. 2014). The effects of $PM_{2.5}$ exposure on type 2 diabetes were added in GBD 2017 (GBD 2017 Risk Factors Collaborators 2018) and neonatal disorders were added in GBD 2019 (GBD 2019 Risk Factors Collaborators 2020). The risk functions for IHD and cerebrovascular disease are age-specific with five-year age intervals from 25 years of age, while singular age-group risk functions are applied for lung cancer, COPD, ALRI, and type 2 diabetes.

The IER function specifies the relationship between annual $PM_{2.5}$ exposure and the relative risk (RR) of a health effect. The RR increases as $PM_{2.5}$ exposure level increases. The RR is the risk of a health effect from exposure to $PM_{2.5}$ relative to the risk of the health effect if there is no exposure to $PM_{2.5}$ or if $PM_{2.5}$ exposure is below a theoretical minimum-risk exposure level (TMREL). The TMREL used in the GBD 2019 is a uniform distribution of $PM_{2.5}$ between 2.4 and 5.9 μg/m^3.

The IER has two main advantages over the methods that were previously used to estimate the health effects of $PM_{2.5}$. First, IER allows for prediction of RR of health effects over a very large range of $PM_{2.5}$ concentrations. Second, IER enables the estimation of health effects based on a country's specific baseline structure of mortality, instead of the one-size-fits-all function that was previously available and ignored intercountry differences in the structure of mortality.

The method for estimating the health effects of $PM_{2.5}$ exposure is explained in GBD 2019 Risk Factors Collaborators (2020) (see Supplementary Appendix 1). The GBD 2019 first estimates the health effects of the total exposure to ambient $PM_{2.5}$ and $PM_{2.5}$ household air pollution from household use of solid fuels for cooking, and then apportions the health effects to ambient $PM_{2.5}$ and household $PM_{2.5}$ air pollution. The annual health effects of annual $PM_{2.5}$ exposure are estimated as follows:

$$B = D * PAF_{PM} \quad \text{(B.1)}$$

where *B* is annual number cases of deaths or illness from $PM_{2.5}$ among the exposed population, *D* is annual baseline number of cases of deaths or illness among this population, and PAF_{PM} (population attributable fraction) is the fraction of baseline cases that is attributable to $PM_{2.5}$ exposure among this population. PAF_{PM} and *B* are calculated for each type of health effect covered by the GBD 2019. Annual baseline cases, *D,* for each type of health effect for Bangladesh is taken from the GBD 2019 (see www.healthdata.org).

PAF for each health effect included in the GBD 2019 is calculated as follows:

$$PAF_{PM} = \frac{P_A(RR_A-1)+P_H(RR_H-1)}{P_A(RR_A-1)+P_H(RR_H-1)+1} \quad \text{(B.2)}$$

where P_A is the share of the population that is exposed only to ambient $PM_{2.5}$ (that is, the population not using solid fuels for cooking), P_H is the share of the population that uses solid fuels for cooking, RR_A is the relative risk of health effects from ambient $PM_{2.5}$ among the population exposed only to ambient $PM_{2.5}$, and RR_H is the relative risk of health effects from $PM_{2.5}$ among the population exposed to $PM_{2.5}$ household air pollution. $P_A + P_H = 1$.

The size of the relative risks of health effects among the population only exposed to ambient $PM_{2.5}$ is:

$$RR_A = RR(AAP) / RR(TMREL) \quad \text{(B.3)}$$

where *RR(AAP)* is the relative risk of health effects at annual $PM_{2.5}$ = AAP and *RR(TMREL)* is the relative risk at $PM_{2.5}$ = TMREL. These relative risks are reported by the GBD 2019 for each type of health effect for a range of annual $PM_{2.5}$ from 0.01 to 2,500 μg/m^3 (see http://ghdx.healthdata.org/record/ihme-data/global-burden-disease-study-2019-gbd-2019-particulate-matter-risk-curves). TMREL may be chosen within the range of 2.4–5.9 μg/m^3 used by the GBD 2019, or TMREL may be chosen to be larger or smaller. TRMEL may also be chosen as zero, in which case RR(TMREL) = 1.

The size of the relative risks of health effects among the population exposed to household air pollution $PM_{2.5}$ is:

$$RR_H = RR(HAP{+}AAP) / RR(TMREL) \quad \text{(B.4)}$$

where *RR(HAP+AAP)* is the relative risk at exposure level $PM_{2.5}$ = HAP+AAP. This exposure level includes both exposure to $PM_{2.5}$ from the use of solid fuels (HAP) and exposure to ambient $PM_{2.5}$ (AAP). HAP+AAP is a so-called personal exposure level that is typically measured over a 24-hour to 48-hour period by a measurement device attached to a person (and assumed to reflect long-term exposure). The exposure level is generally different for each household member due to differences in activity patterns. Most personal exposure measurement studies have been for adult women, who usually are exposed to the highest level of $PM_{2.5}$ in households cooking with solid fuels. The GBD 2019 uses a fraction of adult women exposure equal to 0.64 for adult men and 0.85 for children. Because of these differences in exposure levels, PAF is calculated separately for adult females, adult males, and children under the age of five years.

The GBD 2019 then apportions the PAF_{PM} to ambient and household air pollution as follows:

$$PAF_{AAP} = \frac{AAP}{AAP + P_H HAP} * PAF_{PM} \quad \text{(B.5)}$$

$$PAF_{HAP} = \frac{P_H HAP}{AAP + P_H HAP} * PAF_{PM} \quad \text{(B.6)}$$

where PAF_{AAP} and PAF_{HAP} are the population attributable fractions of deaths and illnesses due to ambient $PM_{2.5}$ and household air pollution $PM_{2.5}$ from the use of solid fuels, respectively; *AAP* is annual ambient $PM_{2.5}$; *HAP* is personal $PM_{2.5}$ exposure from the use of solid fuels; and P_H is the share of the population using solid fuels for cooking.

This approach to apportioning the health effects of $PM_{2.5}$ ensures that:

$$PAF_{PM} = PAF_{AAP} + PAF_{HAP} \quad \text{(B.7)}$$

The GBD 2019 estimates PAF_{PM}, PAF_{AAP}, and PAF_{HAP} at small geographic units over which health effects are summed to the national, state, province, or city level. Each geographic area is a 0.1° x 0.1° grid (corresponding to 11 x 11 km at the equator).

However, equations B.5 and B.6 are less accurate if the *PAFs* are estimated for large geographic units, as done in this report for Bangladesh. In this case, an alternative approach to apportioning the health effects uses the following three steps:

Step 1:

$$PAF^{P}_{AAP} = \frac{P_A(RR_A - 1)}{P_A(RR_A - 1) + 1} \quad \text{(B.8)}$$

$$PAF^{P}_{HAP} = \frac{P_H(RR_H - 1)}{P_H(RR_H - 1) + 1} \quad \text{(B.9)}$$

which are "partial" PAFs for the population exposed only to ambient $PM_{2.5}$ and the population exposed to household air pollution (the population using solid fuels). RR_H in the "partial" PAF for household air pollution is for exposure level HAP+AAP. The next step involves separating the effects of AAP and HAP and adding the effects to the PAFs in equations B.8 and B.9.

Step 2:

$$PAF_{AAP}^{F} = PAF_{AAP}^{P} + PAF_{HAP}^{P} * AAP/(AAP + HAP) \quad \text{(B10)}$$

$$PAF_{HAP}^{F} = PAF_{HAP}^{P} * HAP/(AAP + HAP) \quad \text{(B.11)}$$

The result in Step 2 is such that:

$$PAF_{AAP}^{F} + PAF_{HAP}^{F} > PAF_{PM} \quad \text{(B.12)}$$

The final step involves adjusting the two PAFs downwards so that the sum is equal to PAF_{PM}.

Step 3:

$$PAF'_{AAP} = \frac{PAF_{AAP}^{F}}{PAF_{AAP}^{F} + PAF_{HAP}^{F}} * PAF_{PM} \quad \text{(B13)}$$

$$PAF'_{HAP} = \frac{PAF_{HAP}^{F}}{PAF_{AAP}^{F} + PAF_{HAP}^{F}} * PAF_{PM} \quad \text{(B.14)}$$

The two approaches give identical PAFs for $P_H = 0$ and $P_H = 1.0$. However, for $0 < P_H < 1$, the GBD approach results in a smaller PAF for ambient $PM_{2.5}$ and a larger PAF for household air pollution $PM_{2.5}$ than the alternative approach described in steps 1–3. The difference can be quite large when $PM_{2.5}$ exposure from household air pollution is substantially higher than from ambient $PM_{2.5}$ and increases as P_H approaches 0.5 from either 0 or from 1.0. Therefore, the approach in steps 1–3 is recommended for estimating the health effects of ambient air pollution with exposure data reflecting relatively large geographic units, such as city by city, state by state, province by province, or urban and rural.

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Appendix C. Blood Lead Levels and Sources of Lead Exposure

C.1 Blood lead levels in children and adults

Six studies of children's BLLs in Dhaka are presented in table C1. These studies are the ones that best reflect the general BLL of the children in the city and metropolitan area since the banning of lead in gasoline in Bangladesh in 1999. Mean BLL declined from 15 µg/dL in 2000 to 7.6 µg/dL in 2022.

Table C.1 Mean blood lead levels among children in Dhaka

Location	Description	Age of subjects (years)	Sample size	Mean BLL (µg/dL)	Publication year	Source	Study year(s)
Dhaka city	Children throughout Dhaka city	2-4	500	7.6	2022	1	2022
Dhaka Division	Children from Araihazar Upazila in Narayanganj District in Dhaka Division	14–16	697	9.9	2018	2	2013–16
Dhaka City	Children from low-income sections of Mirpur in Dhaka City	< 2	729	8.2	2018	3	2009–12
Dhaka Division	Children from Araihazar Upazila in Narayanganj District in Dhaka Division	8–11	303	11.5	2011	4	2008
Dhaka	Children from five neighborhoods in Dhaka City	7–16	73	12.0	2011	5	2008
Dhaka	Children from five schools representing various geographic locations and socioeconomic strata in Dhaka	4–12	779	15.0	2001	6	2000

Sources: (1) icddr,b, n.d. (2) Wasserman et al. 2018; (3) Raihan et al. 2018; (4) Wasserman et al. 2011; (5) Linderholm et al. 2011; (6) Kaiser et al. 2001.

Four additional studies shed light on children's BLLs in rural and peri-urban Bangladesh (table C.2)

Table C.2 Blood lead levels among children in rural and peri-urban Bangladesh

Location	Description	Age of subjects	Sample size	Mean BLL (µg/dL)	Publication	Source	Study year(s)
Dhaka Division	Children from rural Sirajdikhan Upazila	20–40 months	383	9.1	2020; 2018	1, 2	2010–13
Rajshahi Division	Children from rural Pabna Upazila	20–40 months	351	4.5	2020	1	2010–13
Rangpur Division	Children from one rural school in the northern area of Chirirbandar, Dinajpur District	< 16 years	197	7.3	2012	3	2007–09
Dhaka Division	Children from peri-urban area in Azampur, Uttara 16 km northeast of Dhaka	< 13 years	57	2.5	2009	4	2007–08

Sources: (1) Gleason et al. 2020; (2) Woo et al. 2018; (3) Mitra et al. 2012; (4) Mitra et al. 2009.

Three relevant studies of BLLs were identified for adults during the preparation of this report (table C.3).

Table C.31 Blood lead levels among adults in Bangladesh

Location	Description	Age of subjects	Sample size	Mean BLL (µg/dL)	Publication	Source	Study years
Dhaka Division	Pregnant women from rural Sirajdikhan Upazila	Mean 23 years	383	7.3	2020	1	2010–13
Rajshahi Division	Pregnant women from rural Pabna Upazila	Mean 23 years	351	2.7	2020	1	2010–13
Mymensingh and Dhaka Divisions	Pregnant women from rural Mymensingh, Tangail, and Kishorenganji districts	Mean 24 years	430	4.7	2018	2	2012–13
Dhaka Division	Adults from rural communities in Araihazar	25–64 years	155	11.9	2019	3	2006–09
Chittagong Division	Adults from rural communities in Matlab	25–64 years	100	3.5	2019	3	2006–09

Sources: (1) Gleason et al. 2020; (2) Forsyth et al. 2018; (3) Bulka et al. 2019.

C.2 Lead exposure from soil, dust, and drinking water

Twenty-two studies of lead concentrations in soil and dust in Bangladesh are summarized in Majumder et al. (2021). Average lead concentrations in agricultural soils, garden soils and roadside soils and dust are 64–87 mg/kg (ppm). Lead concentrations are substantially higher in many industrial and mining areas and reached 224–445 mg/kg at three locations studied. Lead concentrations in soil are often much higher at ULAB recycling sites. Lead concentrations reached over 100,000 mg/kg with a mean of 1,400 mg/kg at two abandoned sites in Kathgora, Savar in Dhaka Division before they were rehabilitated in 2018 (Chowdhury et al. 2021; McCartor and Nash 2018).

Lead in air was a major source of lead ingestion during the times of leaded gasoline. Main sources of lead in air now include lead smelting and battery recycling, mining, resuspended dust containing lead, and possibly burning of agricultural residues containing lead. Majumder et al. (2021) reports lead concentrations in air in eighteen locations from six studies. Five of the studies were published between 2012 and 2018 and one in 2003. Mean lead air concentrations were 0.36 $\mu g/m^3$ with a range from 0.09 to 1.00 $\mu g/m^3$ in sixteen of the locations. In Munshiganj, Pb air concentrations averaged 1.22 $\mu g/m^3$ in eight residential air samples and as high as 377 $\mu g/m^3$ at a battery manufacturing plant (Woo et al. 2018).

Lead exposure also comes from drinking water. As many as 86 percent of the population in Bangladesh receives drinking water from tubewells/boreholes (BBS 2021; BBS/UNICEF 2019). About 12 percent of the population has piped tap water supply and two percent has drinking water from other sources. Overall, well over 95 percent of the population rely on groundwater (Shamsudduha et al. 2019). A review of water pollution in Bangladesh reports lead concentrations in groundwater from four studies conducted in seven locations (Hasan, Shahriar, and Jim 2019). Lead concentrations were 1 µg/L or less in six of the locations. In the seventh location, Rajshahi City, measurements were conducted from 180 representative shallow tubewells and 60 deep tubewells in forty locations in the City. Mean lead concentrations were 1,167 µg/L in the shallow tubewells and 1,120 µg/L in the deep tubewells (Mostafa, Uddin, and Haque 2017).

A most recent review and meta-analysis reports lead concentrations in groundwater from four additional studies (Parvin, Haque, and Tareq 2021). Lead concentrations were less than 1 µg/L or below detectable levels in three of the studies, and 70 µg/L in Dinajpur coal mining area (Bhuiyan et al. 2010). A recent study of household water collected at eleven sampling points throughout northern and southern areas of Dhaka City found lead concentrations of less than 10 µg/L in all samples. Precise concentrations were not reported (Jamal et al. 2020). (See table C.4.)

Table C.4 Lead (Pb) concentrations in soil and dust in Bangladesh | *mg/kg*

	Agricultural soils	Industry and mining area soils	Garden soils	Roadside soils and dust
Minimum	7	12	56	46
Maximum	119	445	87	148
Mean	64	162	70	87
Median	72	67	69	68

Source: World Bank produced from Majumder et al. (2021).

C.3 Lead exposure from food

Lead concentrations in rice, vegetables and fish in Bangladesh are reported by three review studies (Islam et al. 2018a; Kumar et al. 2022; Majumder et al. 2021) and some individual studies. These three food groups constitute nearly 80 percent of daily quantity of food consumption in Bangladesh. Islam et al. (2018a) reviewed nine studies of vegetables and five studies of fish. Majumder et al. (2021) reviewed five of the same studies of vegetables as well as two additional studies. Majumder et al. also reviewed seven studies of fish, two studies of rice, and six studies of other foods. Kumar et al. (2022) reviewed thirty studies on measurements of Pb contamination in agricultural foods and food products. These studies contained lead measurements of 35 kinds of vegetables, 5 kinds of pulses, 3 kinds of cereals, and 10 kinds of fruits.

Rice: Rice is the single most important food consumed in Bangladesh, accounting for nearly half of daily food weight intake. Pb concentrations ranged from 0.08 to 9.64 mg/kg with mean and median of 2.23 and 0.65 mg/kg, respectively. The high of 9.64 mg/kg is attributed to unusually high concentrations of Pb in groundwater used for irrigation at the study location. The second highest concentration of 7.48 mg/kg was likely due to an abandoned lead acid battery recycling workshop that had contaminated surrounding soils (Kumar et al. 2022). Jahiruddin et al. (2017) report on Pb concentrations in rice from measurements in four subdistricts (upazilas) in the Dhaka and Mymensingh Divisions. Measurements were undertaken of dry season irrigated Boro rice and wet season rainfed Aman rice, with mean concentrations of 0.26 and 0.15 mg/kg respectively (table C.5). Mean concentrations varied substantially across locations and were consistently higher in irrigated rice than in rainfed rice (table C.6).

Table C.5 Pb concentrations in Aman and Boro rice | *mg/kg*

	Boro rice (dry season)	Aman rice (wet season)
Minimum	0.11	0.06
Maximum	0.60	0.35
Median	0.25	0.12
Mean	0.26	0.15

Source: Jahiruddin et al. 2017.

Table C.6 Mean concentrations of Pb in rice grains | *mg/kg*

	Irrigated	Rainfed
Faridpur Sadar	0.18	0.12
Saltha	0.20	0.09
Gazipur Sadar	0.31	0.20
Mymensingh Sadar	0.26	0.12

Source: Jahiruddin et al. 2017.

The Pb measurements reported in Jahiruddin et al. (2017) and Kumar et al. (2022) are not nationally representative since samples are often disproportionately from locations with significant sources of Pb pollution. Pb concentrations somewhere between the lowest and median values of measurements (0.08–0.2 mg/kg) reported by Jahiruddin may therefore provide a more accurate reflection of nationwide Pb concentrations than the means reported by Kumar et al. Nationwide concentrations may, however, be lower. Real, Azam, and Majed (2017) sampled ten rice varieties from Kawran Bazar, the largest wholesale market in Dhaka, and found Pb concentrations of 0.0–0.08 mg/kg.

Vegetables: Vegetables are the second most important source of food in terms of daily intake weight. Kumar et al. (2022) reported measurements of Pb in 35 kinds of vegetables. The mean Pb concentration was 0.87 mg/kg in 22 of the vegetables with multiple studies, and 1.16 mg/kg in the other 13 vegetables. The studies showed a large range in Pb concentration for each kind of vegetable. For the two vegetables with the most studies, the range was from less than 0.01 to over 2.5 mg/kg.

Eleven studies reviewed by Islam et al. (2018a) and Majumder et al. (2021) reported a wide range of mean Pb concentrations from 0.017 mg/kg in vegetables sampled at markets to as high as 11.5–15.5 mg/kg around industrial areas in Dhaka. Four studies with measurements of 7–10 kinds of vegetables reported means in the range of 0.5–0.8 mg/kg (table C.7).

Table C.7 Pb concentrations in vegetables in Bangladesh (mg/kg)

# of vegetables	Location	Mean	Median	Reference	Source [a]
7	Overall country: From markets	0.017	0.007	Shaheen et al. 2016	I
2	Kawran Bazar wholesale market, Dhaka	0.017	0.017	Real, Azam, and Majed 2017	I
8	Jhenaidah Industrial Area	0.5	0.5	Islam et al. 2018b	M
10	Around the Paira River, Patuakhali	0.6	0.4	Islam et al. 2015	I&M
7	Pakshi, Pabna	0.6	0.4	Tasrina and Rowshon 2015	I
8	Dhaka: Surrounding the Turag River	0.8	0.2	Islam and Hoque 2014	I
2	Chittagong: Vatiary industrial area	0.9	0.9	Parvin, Sultana, and Zahid 2014	I&M
2	Gazipur: Near highway road	3.2	2.9	Naser et al. 2012	I&M
5	Rural area of Satkhira district	6.9	5.2	Uddin, Hasan, and Dhar 2019	M
1	Dhaka: Surrounding Hazaribagh industrial area	11.5	11.5	Mottalib et al. 2016	I&M
5	Surrounding Dhaka export processing zone	15.5	14.2	Ahmad and Goni 2010	I&M

Source: World Bank based on Islam et al. (2018a) and Majumder et al. (2021).
Note: [a] I = Islam et al. 2018a; M = Majumder et al. 2021.

Results from additional studies of vegetables are presented in table C.8. Mean Pb concentrations range from 0.43 mg/kg in brinjal (eggplant) in northern Bangladesh to 8.15 and 8.4 mg/kg in two industrial area. Brinjal is the second most important vegetable in Bangladesh in terms of consumption. Bushra et al. (2022) sampled four brinjals directly from the field at each of twenty locations in two brinjal-producing upazilas in Jamalpur district. Pb concentrations ranged from 0.2 to 0.73 mg/kg with a mean and median of 0.43 and 0.39 mg/kg, respectively.

The study also measured Pb concentration in the soil at the exact same locations as brinjal was sampled and found a mean concentration of 16.9 mg/kg. Haque et al. (2021) measured Pb in ten kinds of commonly consumed vegetables sampled from (a) Savar Kacha Bazar wholesale vegetable market in Savar Municipality, Savar Upazila northwest of Dhaka City; (b) agricultural fields in a nonindustrial area in Dhamrai Upazila about 50 kilometers northwest of Dhaka City; and (c) a heavily industrialized area in Savar Upazila. Mean Pb concentration in vegetables from the wholesale market was 1.03 mg/kg.

This compares to 0.64 and 2.0 mg/kg in vegetables from the nonindustrial and industrial areas, respectively. Sultana et al. (2022) sampled nine kinds of commonly consumed vegetables from the Kawran Bazar wholesale market. This market is a supply center for vegetables to the entire Dhaka City. Samples were collected four times over a two-month period. Pb was detected in twelve of the 36 samples. Pb concentration in the twelve positive samples ranged from 0.68 to 6.0 mg/kg, with a mean Pb of 2.8 mg/kg. Mean Pb concentration in the overall sample was 0.93 mg/kg.

Table C.8 Pb concentrations in vegetables in Bangladesh from additional studies (mg/kg)

# of vegetables	Location	Mean	Source
1	Brinjal-producing upazilas in Jamalpur district	0.43	Bushra et al. 2022
7	Fields in Khulna	2.69	Dhar et al. 2019
10	Near Mongla industrial area	8.15	Ara et al. 2018a
6	Five locations in Jashore	5.45	Ara et al. 2018b
10	Savar Kacha Bazar wholesale market in Savar Municipality	1.03	Haque et al. 2021
10	Nonindustrial area in Dhamrai Upazila	0.64	Haque et al. 2021
10	Heavily industrialized area in Savar Upazila	2.00	Haque et al. 2021
9	Kawran Bazar wholesale market in Dhaka	0.93	Sultana et al. 2022
10	Tangail Industrial Area	8.40	Proshad et al. 2018

Sources: As noted in the table.

Measurements of Pb concentrations in vegetables sampled at wholesale markets may provide the best indication of population exposure. Four of the studies reported above are from markets and are presented in table C.9. Two of the studies show very low Pb concentrations. This includes a study from fourteen village markets and three urban markets across Bangladesh with mean Pb concentrations ranging from 0.005 to 0.057 mg/kg in the vegetables, from 0.003 to 0.017 mg/kg in two of the fruits, and 0.642 mg/kg in mango (Shaheen et al. 2016). The two others show mean concentrations of 0.93 and 1.03 mg/kg. The studies by Real, Azam, and Majed (2017) and Sultana et al. (2022) are both from Kawran Bazar in Dhaka and show very different Pb concentrations, indicating that larger samples over a longer period of time covering both the rainy and dry seasons may be required to provide more accurate perspectives on Pb concentrations in vegetables nationally.

Table C.9 Pb concentrations in vegetables sampled from markets (mg/kg)

# of vegetables	Location	Mean	Reference
7	Overall country: From markets	0.02	Shaheen et al. 2016
2	Kawran Bazar wholesale market, Dhaka	0.02	Real, Azam, and Majed 2017
10	Savar Kacha Bazar wholesale market in Savar Municipality	1.03	Haque et al. 2021
9	Kawran Bazar wholesale market in Dhaka	0.93	Sultana et al. 2022

Sources: As noted in the table.

The studies of vegetables show large variation in mean Pb concentrations. Most of the studies from nonindustrial areas show mean concentrations in the range of 0.4 to 1.0 mg/kg. According to these studies, it appears that Pb in vegetables may be higher than in rice.

Fish: Fish is the third most important food group in Bangladesh in terms of per capita quantity of consumption and the most important in terms of proteins. Bangladesh ranked third in the world in inland capture fisheries and fifth in culture fisheries production in 2019 (GoB 2020) and fishery production has increased nearly six-fold from 1985 to 2019. Inland culture fisheries experienced the highest growth rate at 9.2 percent per year, followed by marine fisheries at 3.8 percent per year and inland capture fisheries at 2.9 percent per year. Islam et al. (2018a) and Majumder et al. (2021) reviewed seven studies of Pb concentrations in fish from six rivers. Mean concentrations ranged from 0.04 to 9.97 mg/kg (table C.10). Mean concentrations were highest in fish from sampling points in Dhaka in the Buriganga River and in Chittagong in the Karnafuli River. Mean concentrations in the three studies with the lowest Pb levels ranged from 0.04 to 0.74 mg/kg.

Table C.10 Pb concentrations in fish sampled from rivers in Bangladesh (mg/kg)

	# fish species	Pb (mg/kg)	Reference	Source [a]
Buriganga River	5	3.46	Ahmed et al. 2016	I&M
Buriganga River	6	9.97	Ahmad et al. 2010	I&M
Karnafuli River	4	3.32	Islam et al. 2013	I&M
Paira River	8	0.68	Islam and Habibullahalmamun 2017	I&M
Meghna River	6	2.20	Bhuyan et al. 2016	I
Korotoa River	1	0.74	Islam et al. 2015	M
Rupsha River	5	0.04	Samad et al. 2015	M

Source: World Bank based on Islam et al. (2018a) and Majumder et al. (2021).
Note: [a] I = Islam et al. 2018a; M = Majumder 2021.

Majumder (2022) presents studies of Pb in fish from captured fisheries. Mean concentrations range from 0.13 to 11.6 mg/kg (table C.11). Four of the studies measured Pb in three to seven fish species and four measured Pb in a single species (pangasius or tilapia). Mean Pb concentrations were 0.13 to 0.55 mg/kg in three of the studies, 1.35 to 1.67 mg/kg in three other studies, and 6.26 to 11.6 mg/kg in two studies. Some of the studies found high Pb concentration in commercial feed used at fish farms with mean Pb ranging from 6 to 10 mg/kg. These Pb concentrations in feed were highly correlated with Pb concentrations in farmed fish (Kundu et al. 2017; Saha, Mottalib, and Al-Razee 2021).

Table C.11 Pb concentrations in cultured fish in Bangladesh (mg/kg)

# of species	Location	Mean Pb	Reference
3	Cultured pangas, tilapia, and koi from markets across 30 agro-ecological zones	0.04	Ahmed et al. 2015
5	Cultured fish from Mymensing Sadar	0.43	Gosh et al. 2021
4	Rajshahi City (fish farms)	0.55	Mortuza and Al-Misned 2015
1	15 Tilapia ponds in Mymensingh	1.35	Alam and Haque 2021
1	15 Pangas ponds in Mymensingh	1.63	Alam and Haque 2021
1	Pangasius from six ponds at two fish farms in Noakhali	1.67	Das et al. 2017
7	Southern Part of Bangladesh (fish farms)	6.26	Saha, Mottalib, and Al-Razee 2021
1	9 Tilapia farms in Mymensingh	11.6	Kundu et al. 2017

Source: World Bank adapted from Majumder (2022).

Two studies of Pb in fish from the Kawran Bazar fish market in Dhaka found very divergent concentrations. Real, Azam, and Majed (2017) reported concentrations of 0.04–1.04 mg/kg while Shovon et al. (2017) reported a mean of 7.1 mg/kg in muscles of three common fish species. The studies with the lower mean Pb's may best reflect nationwide population exposure to Pb in fish, while the studies with the higher mean Pb's may indicate exposure levels for a relatively small share of the population. This suggests that nationwide population exposure to Pb from fish could be somewhere in the range of 0.04–0.74 mg/kg for capture fish and 0.13–1.6 mg/kg for culture fish. To calculate daily intake of Pb per person from fish consumption, Pb concentrations in fish reported in mg/kg dry weight must be converted to fresh weight by multiplying by a factor of 0.208 (Saha, Mottalib, and Al-Razee 2021).

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Appendix D. Estimating IQ Losses from Pb in Children

A well-established effect of lead exposure is neuropsychological impairment in children, measured as IQ loss. (Intelligence quotient—IQ—is a score on standardized tests designed to assess intelligence.) This impairment occurs even at blood lead levels (BLLs) of less than 10 μg/dL (Crump et al. 2013; Jusko et al. 2008; Lanphear et al. 2005; Surkan et al. 2007). IQ losses associated with BLLs > 10 μg/dL have been established long ago. Lanphear et al. pooled seven international longitudinal cohort studies in which 17 percent of children had peak BLL below 10 μg/dL (table D.1). One of the pooled studies is Canfield et al. (2003) which represent over 40 percent of the sample of children with BLL below 10 μg/dL in Lanphear et al. The largest study of children with BLL below 10 μg/dL is Surkan et al. (2007).

Table D.1 Recent studies assessing the effect of blood lead level (BLL) on children's IQ score

Type of study	Longitudinal cohort (7 pooled studies)	Longitudinal cohort	Cross-sectional	Longitudinal cohort
	Lanphear et al. 2005	Jusko et al. 2008	Surkan et al. 2007	Canfield et al. 2003
Age of children	< 1 to 5–10 years	0.5–6 years	6–10 years	6 months to 5 years
Mean BLL (μg/dL)				
• Concurrent	9.7	5.0	2.2	5.8
• Lifetime	12.4	7.2		7.4
• Peak	18.0	11.4		11.1
Number of children	1,333	174	408	172
Children with BLL < 10 μg/dL	244 (peak)	94 (peak)	408 (concurrent)	101 (peak)

Sources: As noted in the table.
Note: Concurrent BLL is the BLL of a child at the time of IQ testing. Lifetime BLL is the mean BLL over the life of the child prior to IQ testing. Peak BLL is the highest BLL measured prior to IQ testing.

Crump et al. (2013), using the same pooled data as in Lanphear et al., took the analysis further. Crump's study confirmed that the log-linear function is a better predictor of IQ than a linear function. The log-linear function in Crump et al. is:

$$\Delta IQ = \beta \ln(BLL_1+1) \quad \text{(D.1)}$$

With a theoretical minimum-risk exposure level (TMREL) of X_0, below which BLLs is assumed to have no effect on IQ, the function becomes:

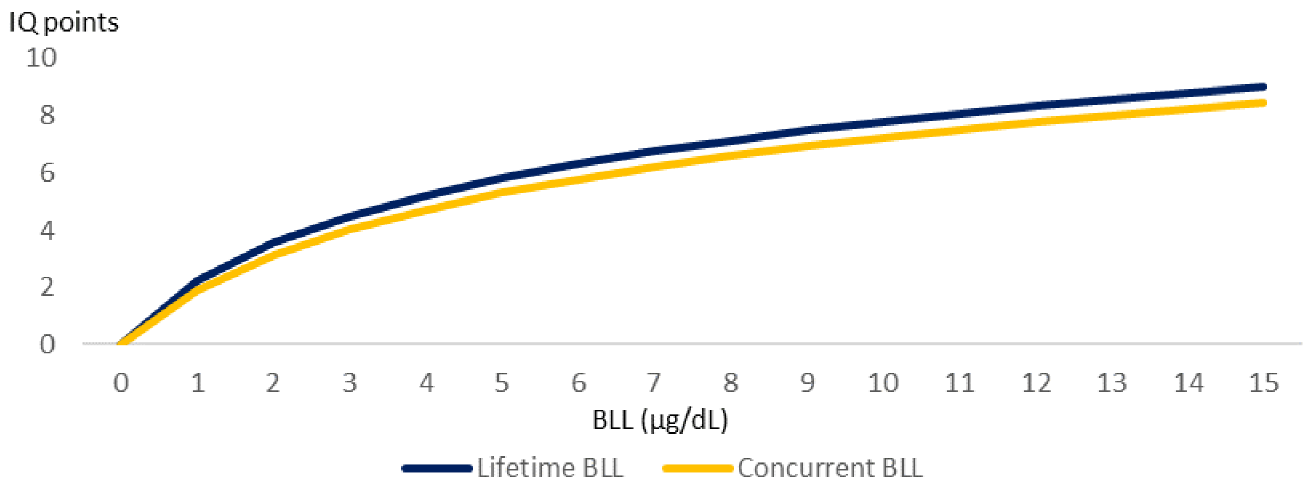
$$\Delta IQ = \beta \ln(BLL+1) \quad \text{for } BLL \geq X_0 \quad \text{(D.2a)}$$

$$\Delta IQ = 0 \quad \text{for } BLL < X_0 \quad \text{(D.2b)}$$

Crump et al. estimated the β coefficient for several measures of BLLs and concluded that concurrent BLLs (BLLs at the time of or just before an IQ test) provide the best description of the relationship between BLL and IQ. Most BLL measurement studies, however, involve samples of children of various ages (for example, ages 0–5 years or 0–7 years) with mean BLLs corresponding closer to lifetime BLLs (mean BLL from age 0 till the time of IQ test) than to concurrent BLLs.

IQ losses based on lifetime and concurrent BLLs are compared in figure D.1 using equation D.1. IQ losses are somewhat larger for lifetime BLLs, with concurrent BLLs converted from lifetime BLLs by a factor of 0.78. The BLLs in the Lanphear et al. studies suggest that concurrent BLLs at ages 5 to 7 years are about 78 percent of lifetime BLLs. Therefore, lifetime BLLs are multiplied by a factor of 0.78 to arrive at estimates of concurrent BLLs. The difference is 0.43–0.54 IQ points across the BLL range of 2 to 30 μg/dL, or 14 percent for a BLL of 2 μg/dL, 7.5 percent for a BLL of 10 μg/dL, and 4.7 percent for a BLL of 30 μg/dL. The percentage difference in estimated IQ losses is therefore relatively small. Using concurrent BLLs also introduces an added element of uncertainty as concurrent BLLs will in most cases need to be estimated from lifetime BLLs as most BLL measurement studies do not have large enough sample of children of ages 5–7 years for estimation of concurrent BLLs. Therefore, lifetime BLLs are applied here to estimate IQ losses from lead exposure.

Figure D.1 Loss of IQ points from lead exposure in early childhood



Source: Produced from the log-linear function reported in Crump et al. (2013).
Note: β = 3.246 for lifetime BLL and β = 3.315 for concurrent BLL.

A BLL threshold (X_0) below which there are no impacts on children's IQ has not been identified in the international research literature. Gilbert and Weiss (2006) argue for a BLL action level of 2 µg/dL and Carlisle et al. (2009) for a benchmark of 1.0 µg/dL based on the recent research evidence. The European Food Safety Authority (EFSA) uses a benchmark dose level (BMDL) of 1.2 µg/dL for neurotoxicity in children (EFSA 2013). The United States Environmental Protection Agency (USEPA), in a recent economic analysis of lead abatement, employed three alternative IQ loss models, two of which applied a zero BLL threshold (USEPA 2020). A threshold value of X_0 = 0 µg/dL is applied here.

Total IQ losses in children are estimated by first calculating the children's BLL distribution. The proportion of children (P_i) with BLL in the range x_{i-1} to x_i ($x_{i-1} < x_i$) is:

$$P_i = F_X(x_i, \mu, \sigma) - F_X(x_{i-1}, \mu, \sigma) \quad \text{(D.3)}$$

where $F_X(x, \mu, \sigma)$ is the cumulative log-normal distribution function, x is BLL, and μ and σ are the natural logarithm of the mean and standard deviation of the BLLs, respectively. Total annual IQ losses in children under five years of age are then approximated by the following expression:

$$\Delta IQ_T = \frac{C}{5} \sum_{i=1}^{n} P_i \beta \ln ln \left(\frac{x_i + x_{i-1}}{2} + 1 \right) \quad \text{(D.4)}$$

Box 6.1 where C is the total number of children under five years of age, with the expression divided by five by assuming that the children's IQ points are lost throughout the first five years of life. An interval of $x_i - x_{i-1} = 0.5$ *µg/dL* is applied to estimate IQ losses in this report, with n such that $F_X(x_n, \mu, \sigma) > 0.999$.

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Appendix E. Estimating Health Effects from Pb in Adults

Lead exposure has been found to increase cardiovascular disease (CVD) mortality risk in adults. Brown et al. (2020) identified and reviewed fifteen studies that assessed this relationship, of which four studies met their inclusion criteria for the development of a health impact model that used each study's BLL concentration-response function. All four studies analyzed BLLs of the adult population in the United States from one or more of the nationally representative National Health and Nutrition Examination Surveys (NHANES) from 1988 to 2010 (CDC 2023). Participant BLLs were highest in the earlier surveys and lowest in the most recent survey. About 20 percent of the participants in the earliest survey 1988-1994 had BLLs above 5 μg/dL while this had declined to about 6 percent in the survey period 1999 to 2010 (table E.1).

While all studies had a relatively large number of participants with BLLs of 5–10 μg/dL, the number of participants with BLLs greater than 10 μg/dL is relatively small. This raises questions as to the validity of the shape of the BLL–CVD mortality risk function estimated by the four studies for individuals with BLLs over 10 μg/dL. This is of relevance because over 25 percent of adults in low- and middle-income countries (LMICs) are estimated to have BLLs above this level. A study using the same data from 1988–94 as Menke et al. and Lanphear et al. reports that 6 percent of participants had BLLs over 10 μg/dL and estimates that the risk of CVD mortality is 1.29 for individuals with BLLs over 10 μg/dL relative to individuals with BLLs of 5–10 μg/dL (Schober et al. 2006). This relative risk is somewhat higher than the risk found by Menke et al. and Lanphear et al. for a BLL of 10 μg/dL relative to 5 μg/dL and substantially higher than for a BLL of 15 μg/dL relative to 10 μg/dL. The difference in relative risk of CVD mortality for BLLs over 10 μg/dL is even larger compared to the risk found by Aoki et al. and Ruiz-Hernandez et al. suggesting that the risk functions in the four studies used by Brown et al. may be conservative for BLLs above 10 μg/dL. Similarly, a study using the NHANES from 1976 to 1980 found that the all-cause mortality risk from BLLs of 20–29 μg/dL was as high as 1.46 relative to BLLs below 10 μg/dL (Lustberg and Silbergeld 2002).

Table E.1 Study participant blood lead levels and measurement period

	BLLs of study participants	BLL measurement period
Aoki et al. (2016)	5.3% of sample had BLL of 5–10 ug/dL, and 0.8% had BLL > 10 ug/dL	1999–2010
Menke et al. (2006)	BLLs up to 10 ug/dL	1988–1994
Ruiz-Hernandez et al. (2017)	BLLs of all participants	1988–1994 and 1999–2004
Lanphear et al. (2018)	20% had BLL > 5 ug/dL and 10% had BLL > 6.7 ug/dL	1988–1994

Source: World Bank derived from Brown et al. (2020).

Based on Brown et al., the relative risk (RR) of CVD mortality from lead exposure is derived as:

$$RR = BLL^{\beta} \quad \text{for } BLL \geq 1\ \mu g/dL \qquad \text{(E.1)}$$

with the β coefficient from the four studies given in table E.2. The estimated coefficient varies by a multiple of almost four, implying a wide range in estimated RR of CVD mortality across the four studies. Lanphear et al. (2018) found the largest RR when restricting the analysis to participants with BLL < 5 μg/dL. Menke et al. (2006) found the second largest RR when restricting the sample to participants with BLL < 10 μg/dL. For the full sample of participants, Aoki et al. (2016) found the smallest RR and Lanphear et al. (2018) found the largest.

As reflected by the size of the β coefficient, the estimated magnitude of relative risk of CVD mortality from elevated BLLs is substantially larger in the three studies that used the earlier survey data with higher BLLs (β of 0.245–0.35) than in the Aoki et al. study that used the more recent data with lower BLLs (β of 0.115). This may suggest that the larger relative risks in Lanphear et al. and Ruiz-Hernandez et al. may be more relevant for LMICs since their populations generally have substantially higher BLLs than in HICs. However, the large relative risk in Menke et al. may not be relevant for most LMICs since Menke et al. restricted the sample to participants with BLL < 10 μg/dL.

Table E.2 Estimated β coefficient of the relative risk function for CVD mortality in adults

	β
Lanphear et al. (2018) (for BLL < 5 μg/dL)	0.417
Menke et al. (2006) (for BLL < 10 μg/dL)	0.350
Lanphear et al. (2018)	0.278
Ruiz-Hernandez et al. (2017)	0.245
Aoki et al. (2016) (for whole blood BLL)*	0.115

Source: Derived from Brown et al. (2020) and Aoki et al. (2016).
Note: *Brown et al. (2020) report the risk function from Aoki et al. (2016) for hematocrit corrected BLL. The β coefficient for whole blood BLL presented here is taken from Aoki et al. (2016).

The disease burden from lead exposure is then estimated in several steps. First, the proportion of adults with BLL in the range x_{i-1} to x_i ($x_{i-1} < x_i$) is estimated:

$$P_i = F_X(x_i, \mu, \sigma) - F_X(x_{i-1}, \mu, \sigma) \quad \text{(E.2)}$$

where $F_X(x, \mu, \sigma)$ is the cumulative log-normal distribution function, x is BLL, and μ is the mean and σ the standard deviation of the natural logarithm of the BLLs. The population attributable fraction of disease is then approximated by the following expression:

$$PAF = \sum_{i=1}^{n} P_i[RR\left(\frac{x_i+x_{i-1}}{2}\right) - 1]/(\sum_{i=1}^{n} P_i[RR(\frac{x_i+x_{i-1}}{2}) - 1] + 1) \quad \text{(E.3)}$$

The disease burden (B) in terms of annual cases of CVD mortality due to lead exposure is then estimated by:

$$B = D * PAF \quad \text{(E.4)}$$

where D is the total annual baseline cases of CVD mortality.

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Appendix F. Health Effects of Inadequate Water, Sanitation, and Hygiene

Inadequate water, sanitation, and hygiene (WASH) is directly and indirectly affecting population health. Directly, inadequate WASH causes diarrheal infections and other health effects that in turn lead to mortality especially in young children. Indirectly, inadequate WASH contributes to poor nutritional status in young children through the effect of diarrheal infections (Fewtrell et al. 2007; Larsen 2007; World Bank 2008). Repeated infections, and especially diarrheal infections, have been found to significantly impair weight gains in young children. Studies documenting and quantifying this effect have been conducted in communities with a wide range of infection loads in a diverse group of countries. World Bank (2008) provides a review of these studies. Poor nutritional status in turn increases the risk of child mortality from disease (Black et al. 2008; Fishman et al. 2004; Olofin et al. 2013). Child underweight is the nutritional indicator most commonly used in assessing the risk of mortality from poor nutritional status (Fishman et al. 2004).

F.1 Direct effects

Relative risks (RR) used by the Global Burden of Disease 2019 (GBD 2019) are applied here to estimate the attributable fraction of diarrheal disease morbidity and mortality from inadequate drinking water, sanitation, and handwashing in Bangladesh. The GBD 2019 derived the relative risk estimates for drinking water and sanitation largely from meta-analyses by Wolf et al. (2014; 2018) and for handwashing with soap from meta-analyses by Cairncross et al. (2010) and Rabie and Curtis (2006).

The GBD 2019 distinguishes between four classes of drinking water and whether or not the household treats the water at point of use (table F.1). RRs range from 1 for high quality piped water that is treated by the household to 11.08 for untreated drinking water from unimproved water sources. The RR for treated water is for water filtering. As boiling of water is equally prevalent as filtering in Bangladesh, the RRs reported by the GBD 2019 for filtering is here also applied to boiled water. The RR for filtering or boiling relative to untreated water is the ratio of RR for treated over the RR for untreated—that is, 0.48, indicating that household water treatment reduces the risk of diarrheal disease by 52 percent. The GBD 2019 also includes chlorination as a treatment method. This method is rarely used by households in Bangladesh according to the Bangladesh MICS 2019 is therefore not reported here.

The GBD 2019 distinguishes between “high-quality piped” and “piped water”. According to this classification, piped water in Bangladesh mostly falls into Class II. Water from tubewells/boreholes is Class III. An alternative classification is to assign all piped water and water from tubewells/boreholes as Class I instead of Class II and III, while water from other improved sources would remain as Class III.

According to the GBD 2019 classification, nearly 87 percent of the population in Bangladesh had Class III drinking water (mostly tubewells/boreholes) while nearly 12 percent had Class II (piped water). The alternative classification assigns over 97 percent of the population to Class I (piped water and tubewells/boreholes) (table F.1). The impact of the difference in classification on the estimated attributable fraction of diarrheal disease and mortality from drinking water is substantial as seen further below, but much smaller on the joint attributable fraction from inadequate drinking water, sanitation, and hygiene.

Table F.1 Relative risk of diarrheal disease from drinking water in Bangladesh, 2019

	Treated (filtered or boiled)	RR (GBD 2019)	GBD 2019 classification	Population distribution (%)	Alternative classification	Population distribution (%)
Class I	Yes	1.00	High-quality piped	0	Piped water and tubewell/borehole	9.2
	No	2.08		0		88.0
Class II	Yes	3.31	Piped water	1.1		0
	No	6.88		10.5		0
Class III	Yes	4.33	Other improved	8.3	Other improved	0.1
	No	8.99		78.6		1.2
Class IV	Yes	5.33	Unimproved	0.3	Unimproved	0.3
	No	11.08		1.2		1.2

Source: World Bank based on Bangladesh MICS 2019 (BBS/UNICEF 2019) and GBD Risk Factor Collaborators (2020) Supplement 1.

The GBD 2019 distinguishes between three forms or classes of household sanitation. The relative risks of diarrheal disease and mortality from sanitation are relative to households with flush or pour flush toilets connected to a sewer network or a septic tank (table F.2). An alternative classification is based on the Bangladesh MICS 2019 definition of "safe disposal in situ of excreta from on-site sanitation facilities" which accounts for 90 percent of the population with septic tanks and other improved sanitation. This classification assigns the majority of the population in Class I. As in the case of drinking water, the impact of the difference in classification on the estimated attributable fraction of diarrheal disease and mortality from sanitation is substantial as seen further below, but much smaller on the joint attributable fraction from inadequate drinking water, sanitation, and hygiene.

Table F.2 Relative risk of diarrheal disease from sanitation in Bangladesh, 2019

	RR (GBD 2019)	GBD 2019 classification	Population distribution (%)	Alternative classification	Population distribution (%)
Class I	1.00	Sewer connection or septic tank	30.0	Sewer connection and safe disposal of excreta	76.9
Class II	2.71	Other improved sanitation	54.6	Other improved sanitation	7.7
Class II	3.23	Unimproved sanitation	15.4	Unimproved sanitation	15.4

Source: World Bank based on Bangladesh MICS 2019 (BBS/UNICEF 2019) and GBD Risk Factor Collaborators (2020) Supplement 1.

Handwashing with soap and water is effective in reducing diarrheal disease (Cairncross et al. 2010). The GBD 2019 reports the relative risk of diarrheal disease and mortality from households not having access to a handwashing station with available soap and water, and the Bangladesh MICS 2019 reports that 25 percent of the population do not have access to such a station on household premises (table F.3).

Table F.3 Handwashing with soap and relative risk of diarrheal disease in Bangladesh, 2019

	RR (GBD 2019)	Population distribution
Access to a handwashing station with available soap and water	1.00	74.8
No access to a handwashing station with available soap and water	1.52	25.2

Source: World Bank based on Bangladesh MICS 2019 (BBS/UNICEF 2019) and GBD Risk Factor Collaborators (2020) Supplement.

The attributable fraction (AF) of diarrheal disease and mortality is calculated as follows:

$$AF = \frac{\sum_{i=1}^{n} P_i (RR_i - 1)}{\sum_{i=1}^{n} P_i (RR_i - 1) + 1} \qquad \text{(F.1)}$$

Where P_i with i=1,...,n) is the population distribution and RR_i is the corresponding relative risk in tables F.1–3.

The estimated AFs of diarrheal disease and mortality are presented in table F.4. The largest AF is from inadequate drinking water, followed by sanitation. The joint attributable fraction of diarrheal disease and mortality from inadequate drinking water, sanitation, and handwashing is in the range of 72–95 percent. The joint AF is calculated by $AF^J = 1 - \prod_{k=1}^{n}(1 - AF_k)$ as in Prüss-Üstün et al. (2014), where k refers to drinking water, sanitation, and handwashing.

Table F.4 Estimated attributable fractions of diarrheal disease from inadequate WASH in Bangladesh, 2019 | *% of baseline disease*

	Based on GBD 2019 classifications	Based on alternative classification
Inadequate drinking water	88.0	54.1
Inadequate sanitation	53.3	31.2
Inadequate handwashing with soap	11.6	11.6
Inadequate drinking water, sanitation, and hand hygiene	95.0	72.1

Source: World Bank.

The GBD 2019 also provides a relative risk (RR = 1.32) of acute lower respiratory infections (ALRI) from inadequate handwashing. Based on population distribution in table F.3, the AF of ALRI from lack of handwashing station with soap and water at premises is 7.5 percent.

The disease burden (B) in terms of annual cases of diarrheal disease and mortality due to inadequate drinking water, sanitation, and hygiene is estimated by:

$$B_l = AF_l^J \, D_l \quad \text{(F.2)}$$

where D_l is the total annual baseline number of cases of diarrheal disease and mortality and ALRI morbidity and mortality. D_l for Bangladesh is taken from the GBD 2019 (see www.healthdata.org).

F.2 Indirect effects

Estimating the indirect mortality effects of diarrhea from inadequate WASH is here undertaken in two stages. First, the fraction of under-five child mortality attributable to child underweight is estimated. This follows the methodology in Olofin et al. (2013). Second, a fraction of under-five child mortality from underweight is attributed to diarrheal infections and inadequate WASH using the approach in Fewtrell et al. (2007).

An alternative approach to estimating the fraction of mortality attributable to diarrheal infections is the methodology developed in Larsen (2007) and World Bank (2008). However, this requires estimation of counterfactual prevalence rates of child underweight (prevalence of underweight in the absence of diarrheal infections) from original survey data of child nutritional status. The approach in Fewtrell et al. gives a somewhat lower estimate of indirect mortality from inadequate WASH than the Larsen and World Bank methodology.

Estimates of increased risk of cause-specific mortality in children under five years of age with mild, moderate, and severe underweight are presented in table F.5 based on Olofin et al. (2013).

Table F.5 Relative risk of mortality from underweight in children under five years of age

	Severe	Moderate	Mild	None
Acute lower respiratory infections (ALRI)	10.10	3.11	1.85	1.00
Diarrhea	11.56	2.86	1.73	1.00
Measles	7.73	3.12	1.00	1.00
Malaria	1.29	1.65	1.26	1.00
Other infectious diseases	8.28	1.58	1.54	1.00

Source: Olofin et al. 2013.
Note: Relative risks are in relation to severe, moderate, and mild underweight according to the WHO Child Growth Standards.

These relative risk ratios are applied to prevalence rates of child underweight to estimate attributable fractions (AF_j) of mortality by cause, ***j***, from child underweight as follows:

$$AF_j = \frac{\sum_{i=1}^{n} P_i(RR_{ji} - 1)}{\sum_{i=1}^{n} P_i(RR_{ji} - 1) + 1} \quad \text{(F.3)}$$

where RR_{ji} is relative risk of mortality from cause, ***j***, for children in each of the underweight categories, ***i***, in table 2E.5; and P_i is the underweight prevalence rate. Prevalence rates of child underweight are from the Bangladesh MICS 2019.

Annual cases (M) of mortality from child underweight (by cause, "j", in table F.5) are estimated as follows:

$$M_j = AF_j D_j \quad \text{(F.4)}$$

where D_j is the total annual baseline number of cases of mortality from cause "j" among children under five. D_j for Bangladesh is taken from the GBD 2019 (see www.healthdata.org).

Annual under-five child mortality from inadequate drinking water, sanitation, and hygiene (W) is then estimated as follows:

$$W = \sum_{j=1}^{j=m} \gamma_j M_j \quad \text{(F.5)}$$

where γ_j is the fraction of child underweight mortality (M_j) attributed to inadequate drinking water, sanitation, and hygiene through diarrheal infections in early childhood. WHO (Fewtrell et al. 2007) uses $\gamma_j = 0.5$ for ALRI, measles, malaria, and "other infectious diseases." This is here adjusted by the fraction of diarrheal disease attributed to inadequate drinking water, sanitation, and hygiene in table F.4. "Other infectious diseases" are here limited to meningitis.

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Appendix G. Valuation of IQ Losses

An individual's IQ has an effect on lifetime income. This has long been established by, for instance, Schwartz (1994) and Salkever (1995). The first study estimates that a loss of one IQ point is associated with a 1.76 percent decline in lifetime income. A little over one-quarter is the direct effect on earnings while nearly three-quarters is the indirect effect through reduced schooling, and through reduced labor force participation. The second study estimates that a loss of one IQ point reduces male and female lifetime income by 1.9 and 3.3 percent, respectively, including the effect on labor force participation.

Johnson and Neal (1998) estimated an overall direct and indirect income effect of about 2.8 percent per IQ point with a much larger effect for females than for males as also found by Salkever (1995). The estimate does not include labor force participation effect. Zax and Rees (2002) found a much smaller direct and indirect effect of 0.39–1.39 percent per IQ point for white males. Salkever (2014) argues, however, that this size effect is not representative as the study does not include females and minority groups for which size effects are found to be much larger by Salkever (1995) and Johnson and Neal (1998). The size of the effect of IQ on lifetime income continues to be debated. Grosse (2014) argues that the effect is smaller than found by Salkever (1995) while Salkever (2014a,b) defends the estimates on the basis that other studies often omit females and minorities and do not include the effect on labor force participation.

Attina and Trasande (2013) applied a lifetime income effect of 2 percent per IQ point for their estimate of the cost of lead exposure in children in LMICs. Most recently Grosse and Zhou (2021) applied an effect of 1.4 percent per IQ point as a conservative estimate based on a review of the literature that includes recent studies by Lin, Lutter, and Ruhm (2018) and Lundborg, Nystedt, and Rooth (2014). USEPA (2020) undertook a reanalysis of Salkever (1995) using a more recent version of the data set used by Salkever. The reanalysis found a lifetime income effect per IQ point of 1.86 percent for males (slightly below Salkever (1995)) and 3.4 percent for females (somewhat above Salkever (1995)).

In this report an effect of 2.0 percent decline in lifetime income per lost IQ point is applied to all children eventually participating in the labor force. This is slightly above the value used by Grosse and Zhou (2021) but substantially below the value in Johnson and Neal (1998), Salkever (1995), and USEPA (2020).

Lifetime income for a person that is or will be in the labor force is calculated as follows:

$$PV_0(I) = \sum_{i=k}^{i=n} I_0(1+g)^i/(1+r)^i \quad \text{(G.1)}$$

where PV_0 (I) is the present value in year 2019 of lifetime income, I_0 is annual income in year 2019, g is annual growth in real income, and r is the discount rate of future income. The equation allows for income to start from year k and end in year n. Present value of lifetime income is calculated for a child at the age of 2.5 years—that is, at the midpoint of 0–5 years during which IQ losses are assumed. Therefore, k is the age of entering the labor force less 2.5 years, and n is the age of retirement less 2.5 years.

A person's annual income in year 2019 is calculated as follows:

$$I_0 = GDP_0\, s / L_0 \quad \text{(G.2)}$$

where *GDP* is the country's total GDP, *L* is total labor force, and *s* is labor compensation share of GDP in 2019. ***S*** is from PENN World Table, Version 10.

Annual cost of IQ losses is then:

$$C = \alpha\, PV_0(I)\, p\, \Delta Q_T \quad \text{(G.3)}$$

where α is the effect of IQ on lifetime income (2.0 percent per IQ point), PV_0(I) is the present value of lifetime income in 2019, p is the probability of future labor force participation (LFP), and ΔQ_T is a country's total annual IQ points lost in 2019 due to lead exposure.

The parameter values for equations F.1–3 are presented in table G.1. Long-term future per capita income growth is set at 2.5 percent per year. The discount rate of future income is set at twice the per capita income growth rate as proposed by the World Bank for project economic analysis (World Bank 2016). The probability of future LFP is set at the LFP rate in 2019 reported by the World Bank (2023).

Table G.1 Parameters for estimation of the cost of IQ losses

	Parameter	Bangladesh
Effect of lifetime income per IQ point	α	2.0%
Long-term future income growth per year	g	2.5%
Rate of discounting of future income	r	5.0%
Future labor force participation rate	p	62% (current rate)
Labor force participation (age)		18–65 years

Source: World Bank.
Note: Parameters are from equations G.1 and G.3.

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Appendix H. Valuation of Illness

Two valuation techniques are commonly used to estimate the cost of morbidity or illness. The cost-of-illness (COI) approach includes the cost of medical treatment and value of income and time lost to illness. The second approach equates cost of illness to individuals' WTP for avoiding an episode of illness. Studies in many countries have found that individuals' WTP to avoid an episode of illness is generally much higher than the cost of treatment and value of income and time losses (Alberini and Krupnick 2000; Cropper and Oates 1992; Dickie and Gerking 2002; Wilson 2003).

In most studies of the health effects and cost of air pollution it is estimated that cost of mortality represents 70 to 90 percent of total cost and cost of morbidity or illness represents 10 to 30 percent. It is therefore more important to reach a consensus on valuation of mortality risk than on incidence of morbidity. For infectious diseases from inadequate drinking water, sanitation, and hygiene, the cost of morbidity can be quite a substantial share, especially in countries with low fatality rates (but high nonfatal incidence rates) of these infectious diseases.

Estimating the cost morbidity often requires much more and less accessible baseline health and cost data than estimating the cost of mortality. One option is therefore to use the estimates of "years lived with disability" (YLD) for the relevant illnesses in Bangladesh from the GBD studies. YLD can then be converted to days lived with disease by applying the disability weights in the GBD studies. The cost of days lived with disease can then be estimated.

The approach applied in this report involves the following steps:

1. Estimates of YLDs are converted to days lived with disease by applying the disability weights in the GBD 2019 for Bangladesh (tables H.1–3).
2. The cost of a day lived with disease is then approximated as a fraction of the average daily wage rate to reflect income losses from illness, health expenditure, time losses and the welfare cost of pain and suffering.
3. The cost of a day of illness is also applied to individuals without income because illness prevents most of these individuals from undertaking household work and other activities with a social value, as well as involves all the non-income impacts of illness.

The cost of morbidity is thus estimated as follows. First, days lived with disease (M) are calculated as:

$$M = \sum_{i=1}^{n} M_i = \sum_{i=1}^{n} (YLD_i * 365/d_i) \quad \text{(H.1)}$$

where YLD_i is years lived with disability from disease, *i*, and d_i is the disability weight for disease, *i*. The disability weight for each disease is calculated from the GBD 2019 for Bangladesh.

Disability weight is a measure used in GBD to calculate YLDs from days lived with illness, disease, or injury. The disability weights for the diseases associated with ambient and household $PM_{2.5}$ air pollution exposure; adult lead exposure; and inadequate drinking water, sanitation, and hygiene in Bangladesh are presented in tables H.1–3. The weighted average disability weight for diseases associated with arsenic exposure is 0.056 based on disability weights for twelve noncommunicable disease categories.

Table H.1 Disability weights for Bangladesh for diseases associated with $PM_{2.5}$ exposure

	Disability weights
IHD	0.017
Stroke	0.152
COPD	0.110
Lung cancer	0.231
ALRI	0.060
Type 2 diabetes	0.081

	Disability weights
Neonatal disorders	0.209
Cataract[a]	0.073

Source: Disability weights for Bangladesh are calculated from GBD 2019 data at http://www.healthdata.org/
Note: [a] Morbidity health effect of household air pollution.

Table H.2 Disability weight for Bangladesh for cardiovascular diseases associated with adult Pb exposure

	Disability weight
Cardiovascular disease	0.054

Source: Disability weights for Bangladesh are calculated from GBD 2019 data at http://www.healthdata.org/

Table H.3 Disability weights for Bangladesh for diseases associated with inadequate drinking water, sanitation, and hygiene

	Disability weights
Diarrheal disease	0.112
Typhoid/paratyphoid	0.167
ALRI	0.060

Source: Disability weights for Bangladesh are calculated from GBD 2019 data at http://www.healthdata.org/

Second, the cost (c) of a day lived with disease, i, is thus a fraction of the daily wage rate, with the fraction proportional to the severity of disease:

$$c_i = w\, d_i / D \qquad \text{(H.2)}$$

where *w* is average daily wage rate and d_i disability weight for disease, *i*, and D is a disability weight that corresponds to a severity of disease for which the cost of a disease day is assumed equal to the average wage rate. D is here set at 0.4. This is a disability weight associated with severely restricted work and leisure activity from disease and substantial medical cost—for example, severe COPD (d = 0.41), distance vision blindness (d = 0.19) and Stage V chronic kidney disease (d = 0.57) due to diabetes, and stroke with severity level 3 (d = 0.32) and 4 (d = 0.55).

Third, cost of morbidity (C) is calculated as follows:

$$C = \sum_{i=1}^{n} (c_i\, M_i) \qquad \text{(H.3)}$$

Average daily wage rate is estimated as follows:

$$w = GDP / L / 250 * s \qquad \text{(H.4)}$$

where *GDP* is the country's total GDP, *L* is total labor force, *s* is labor compensation share of GDP, and annual working days is averaging 250. *S* = *0.52* is applied to Bangladesh, using the value for India from PENN World Table, Version 10.

Average wage rates are also used in the cost-benefit analyses of interventions, using projected wage rates for the year 2026 as a midpoint of the time horizon of the analyses till 2030 (table H.4).

Table H.4 Projected GDP per capita and wage rates, 2019–26

	2019	2026
GDP per capita (constant 2019 Tk)	178,280	235,565
Labor force (% of population)	42%	42%
Labor income share of GDP	52%	52%
Rural population share	62.6%	57.2%
Wage rate, daily (constant 2019 Tk)	832	1,100
Rural wage rate, daily (constant 2019 Tk)	606	770
Female rural wage rate, daily (constant 2019 Tk)	484	616
Wage rate, hourly (constant 2019 Tk)	104	137
Rural wage rate, hourly (constant 2019 Tk)	76	96
Female rural wage rate, hourly (constant 2019 Tk)	61	77

Sources: GDP per capita in 2019 is from BBS (2022), labor force and rural population share in 2019 are from World Bank (2023). The remaining figures are World Bank estimates.

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Appendix I. Valuation of Mortality

The predominant measure of the social cost of premature death used by economists is the value of statistical life (VSL). VSL is based on valuation of mortality risk. Everyone in society is constantly facing a certain risk of dying. Examples of such risks are occupational fatality risk, risk of traffic accident fatality, and environmental mortality risks. It has been observed that individuals adjust their behavior and decisions in relation to such risks. For instance, individuals demand a higher wage (a wage premium) for a job that involves a higher occupational risk of fatal accident than in other jobs, individuals may purchase safety equipment to reduce the risk of death, and/or individuals and families may be willing to pay a premium or higher rent for properties (land and buildings) in a cleaner and less polluted neighborhood or city.

Through the observation of individuals' choices and willingness to pay for reducing mortality risk (or minimum amounts that individuals require to accept a higher mortality risk), it is possible to estimate the value to society of reducing mortality risk, or, equivalently, measure the social cost of a particular mortality risk. For instance, it may be observed that a certain health hazard has a mortality risk of 2.5/10,000. This means that, on average, one individual dies from this hazard for every 4,000 individuals exposed. If each individual on average is willing to pay $40 for eliminating this mortality risk, then every 4,000 individuals are collectively willing to pay $160,000. This is the VSL, or the value that individuals collectively are willing to pay to avoid one death. Mathematically it can be expressed as follows:

$$VSL = WTP_{Ave} * 1/R \quad \text{(I.1)}$$

where WTP_{Ave} is the average willingness-to-pay per individual for a mortality risk reduction of magnitude R. In the illustration above, R = 2.5/10 000 (or R = 0.00025) and WTP_{Ave} = $40. Thus, if 10 individuals die from the health risk illustrated above, the cost to society is 10* VSL = 10* $0.16 million = $1.6 million.

The main approaches to estimating VSL are through revealed preferences and stated preferences of people's WTP for a reduction in mortality risk or their willingness-to-accept (WTA) an increase in mortality risk. Most of the studies of revealed preferences are hedonic wage studies, which estimate labor market wage differentials associated with differences in occupational mortality risk. Most of the stated-preference studies rely on contingent valuation methods (CVM), which in various forms ask individuals about their WTP for mortality risk reduction.

Studies of WTP for a reduction in risk of mortality have been carried out in numerous countries. A commonly used approach to estimate VSL in a specific country is therefore to use a benefit transfer (BT) based on meta-analyses of WTP studies from other countries. Many meta-analyses have been conducted in the last two decades. Meta-analyses assess characteristics that determine VSL, such as household income, size of risk reduction, other individual and household characteristics, and often characteristics of the methodologies used in the original WTP studies.

Most of the meta-analyses of VSL are entirely or predominantly based on hedonic wage studies. However, a meta-analysis prepared for the OECD was based exclusively on stated-preference studies, arguably of greater relevance for valuation of mortality risk from environmental factors than hedonic wage studies (Lindhjem et al. 2011; Navrud and Lindhjem 2010; OECD 2012). These stated-preference studies are from a database of more than 1,000 VSL estimates from multiple studies in over 30 countries, including in developing countries (www.oecd.org/env/policies/VSL).

The World Bank (2016) presents a benefit transfer methodology for valuing mortality from environmental health risks, drawing on the empirical literature of VSL, especially OECD (2012). The methodology is applied in the recent publication by the World Bank and IHME (2016) on the global cost of air pollution. The proposed benefit transfer function is:

$$VSL_{c,n} = VSL_{OECD} * \left(\frac{Y_{c,n}}{Y_{OECD}}\right)^{\epsilon} \quad \text{(I.2)}$$

where $VSL_{c,n}$ is the estimated VSL for country **c** in year ***n***, VSL_{OECD} is the average base VSL in the sample of OECD countries with VSL studies ($3.83 million), $Y_{c,n}$ is GDP per capita in country **c** in year ***n***, and Y_{OECD} is the average GDP per capita for the sample of OECD countries ($37,000), and ε an income elasticity of 1.2 for low- and middle-income countries and 0.8 for high income countries. All values are in purchasing power parity (PPP) prices. Therefore, $VSL_{c,n}$ must be converted to local currency using

PPP exchange rates, available in World Bank (2023).

This approach provides a VSL for Bangladesh in the amount of Tk 12.7 million in 2019. The VSL is calculated based on a GDP per capita of Tk 178,280 in 2019 (BBS 2022). VSL increases to Tk 17.7 million in 2026 with rising GDP per capita. The VSL/GDP ratio increases from 71 times GDP per capita in 2019 to 75 in 2026 (table I.1). This increase is due to the income elasticity of 1.2.

Table I.1 Value of statistical life (VSL) in Bangladesh, 2019–16

	2019	2026
GDP per capita (constant 2019 Tk)	178,280	235,565
GDP per capita, PPP (constant 2019 international $)	5,698	7,529
VSL (constant 2019 international $)	405,713	566,798
VSL (constant 2019 Tk)	12,694,133	17,734,234
VSL/GDP per capita ratio	71	75

Sources: GDP per capita in 2019 are from BBS (2022) and GDP per capita, PPP, is from World Bank (2023). Remaining figures are World Bank estimates.

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Appendix J. Adjusting Mortality Estimates for Multiple Risk Factors

Several of the environmental risk factors assessed in this report cause an increase in the same disease among the same population. This is the case for ALRI associated with ambient air pollution (AAP), household air pollution (HAP), and water, sanitation, and hygiene (WASH); for cardiovascular disease associated with AAP, HAP, lead (Pb), and arsenic (As); and for COPD, lung cancer, and type 2 diabetes for AAP and HAP (table J.1).

Table J.1 Disease-specific mortality caused by environmental risk factors

Disease-specific mortality	Environmental risk factors
ALRI	AAP, HAP, and WASH
Cardiovascular disease	AAP, HAP, Pb, Arsenic
COPD, lung cancer, and type 2 diabetes	AAP, HAP

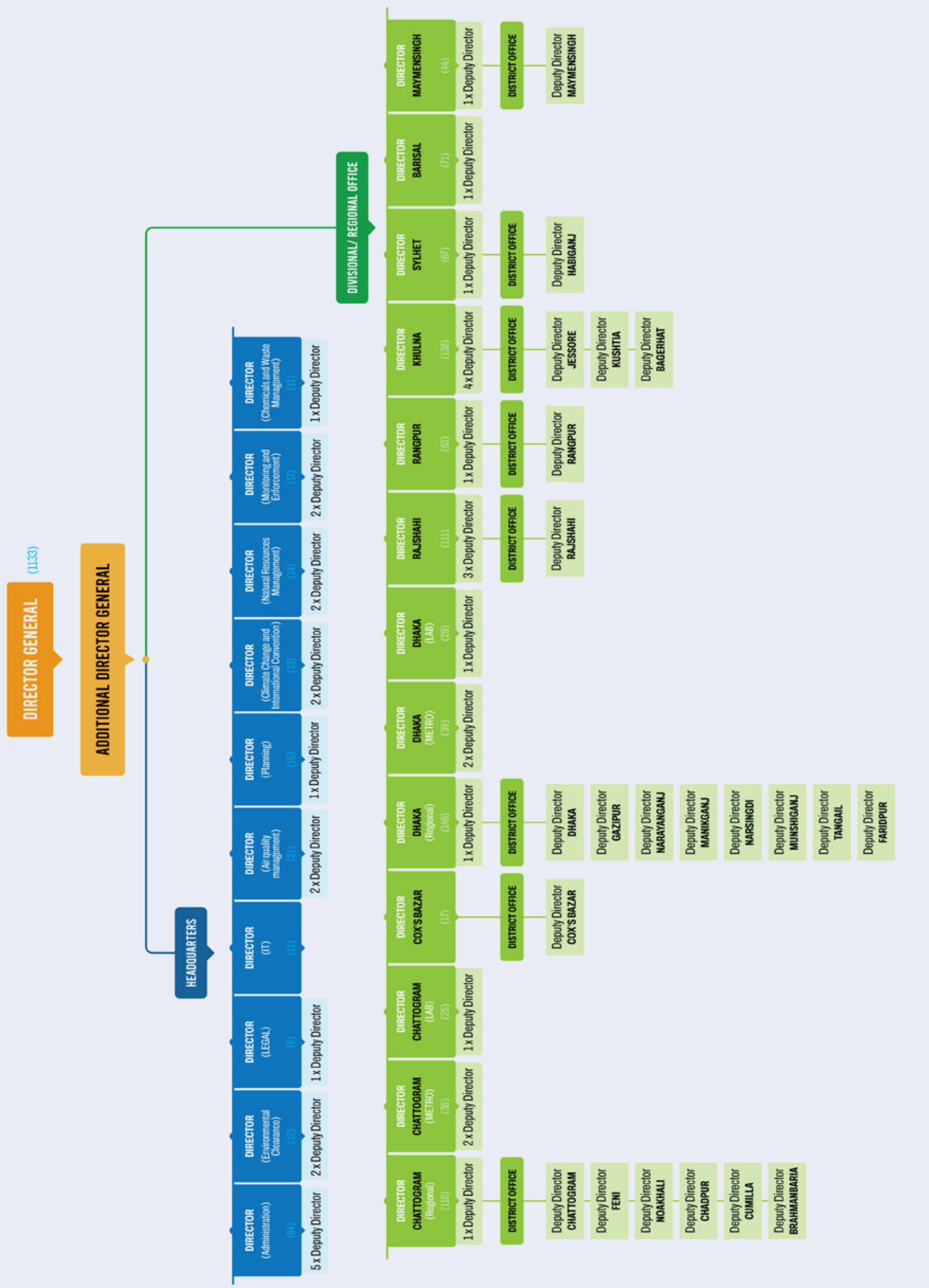
Source: World Bank.

When more than one of the environmental risk factors cause the same disease, then the total disease burden from these risk factors is overestimated if simply added up by risk factor. To avoid this double-counting the joint attributable fraction *(AF^T)* formula for *n* risk factors is applied to estimate total mortality from the specific disease *(i)*:

$$AF_i^T = 1 - \prod_{k=1}^{n}(1 - AF_i^k) \qquad \text{(J.1)}$$

This formula is applied to estimate total disease and mortality from the environmental risk factors assessed in this report.

Appendix K. Organogram of Bangladesh Department of Environment



Source: DoE 2023.

Appendix L. Need for Regular and Reliable Production of Environmental Data and Statistics

For the GoB to prioritize policies and to achieve a green, resilient, and inclusive development (GRID) pathway, better environmental data and statistics are required. This includes environmental pollution monitoring data (for example, ambient air and water quality, solid and water-related waste, hazardous waste, emissions from industries, and so forth), disaggregated biophysical data on ecosystems, data on ecosystem services, and socioeconomic data on the impact of the environment on the local economies and livelihoods, among others. Better environmental data and statistics will contribute to the target monitoring of GoB's 8FYP, allowing for the incorporation of criteria to prioritize and monitor green growth interventions and embed GRID principles in budget planning. Furthermore, such data would enhance polluters' accountability and improve compliance and enforcement of environmental management.

The GoB has already taken steps to improve the availability, quality, and reliability of its environmental statistics. In 2016, the BBS embarked upon an ambitious process to improve environmental statistics and developed the BESF 2016–2030, which aligns with the Statistical Act 2013, the National Strategy for the Development of Statistics, and other relevant policies. The BESF was developed as a strategic action plan for GoB to move towards an integrated approach to collecting, analyzing, and disseminating environmental data and information based on national priorities and future plans, including achieving Bangladesh's green growth potential.

Despite these efforts, the GoB faces several limitations and challenges in its successful implementation of the BESF, resulting in weak disclosure and accessibility of timely environmental data. Specific challenges include (a) lack of inter-ministerial and inter-agency coordination; (b) lack of a common format and platform for collecting, organizing and sharing environmental data; (c) absence of proper mechanisms to ensure the quality of data provided by respective responsible government agencies; (d) insufficient financial resources and inefficient methods for data collection, compilation, processing, and dissemination of environmental data; (e) absence of designated focal point officers in respective data providing government agencies; (f) shortage of skilled human resource capacity, (g) overly ambitious goals for data production that lack prioritization, among others.

There is a strong need to improve the capacity of BBS and relevant data-producing government departments to ensure the sustainable production of timely and quality environmental statistics. To operationalize the Bangladesh Environmental Statistics Framework (BESF) , the GoB needs to (a) improve and/or newly develop mechanisms for inter-agency coordination for the generation, management and sharing of environmental data and statistics; (b) boost human resource capacity of BBS and relevant government ministries and departments, including introducing quality control measures and regular training; (c) introduce innovative technology and data ICT infrastructure for the efficient production, management and public sharing of environmental data and statistics (for example, apps to display real-time automated pollution data, drone technology for monitoring mangrove health, and so forth); (d) invest in strengthening the coverage and quality of environmental and natural capital data and statistics with the specific goal of prioritizing for, tracking the progress of, and streamlining green growth policies; and (e) take a phased approached to data production, starting with the most polluted hotspots and GoB priorities on environmental conservation and sustainable natural resource management. The GoB may also consider the monitoring and reporting of area-based (for example, for airshed, water basin, ecosystems, and so forth) environmental quality data as a legally binding requirement.

Appendix M. Bangladesh Environmental Sustainability and Transformation Project

The BEST project aims to strengthen the capacity of the GoB in environmental management and to pilot new financing mechanisms to promote green investments in targeted sectors. The project is co-financed by the World Bank ($250 million) and the Agence Française de Développement (EUR 40 million) and is planned to be implemented in five years.

Component 1 on Environmental Governance and Infrastructure will support the DoE to (a) develop regulations and policies to expand the regulatory mandate of the DoE from controlling individual pollution sources to protecting and improving environmental quality and promoting green growth, (b) continue decentralization and improve specialization of the DoE with increased human and financial resources, (c) create and capitalize an Environment Fund, (d) enhance institutional capacity and environmental infrastructure for DoE and its key stakeholders on environmental management, including through improved air and water quality monitoring, laboratories, information systems, training and awareness campaigns.

Component 2 on Green Financing for Air Pollution Control will support BB to pilot a green credit guarantee facility to incentivize the financial sector to support green investments to reduce pollution directly or indirectly from the brick kiln sector, municipal waste management, clean cookstove (biogas), and rooftop solar systems. This component will help BB to further develop the country's green financing ecosystem to mitigate or remove regulatory, technological, financial, technical capacity, and market barriers that have prevented the polluting private sector from investing in green technologies and achieving environmental compliance. BB will organize training and technical promotional events to solicit investment demands from all participating financial institutions (PFIs) and the targeted sub-borrowers.

The BB will also select technical institutes, individual experts, or both during project implementation to support PFIs and targeted sub-borrowers on technical, environmental (including climate), health, safety, social, and gender issues of their investments. Furthermore, this subcomponent will support BB in carrying out targeted awareness-raising events to persuade consumers to reduce their demand for products from traditional technologies and increase their demand for green products. It is expected that the informed public and consumers will eventually exert public and market pressure for the targeted sectors to adopt green technologies and improve their environmental performance in a changing environment. Coordination with IFC is ongoing to promote good environment, social, and governance practices among participating financial institutions.

Component 3 on vehicle-inspection control will support BRTA to pilot public-private partnership modalities to develop and operate vehicle inspection centers (VICs) regulating vehicle emissions effectively—a key and growing source of air pollution—in Bangladesh. This component will finance (a) the construction of four new VICs and the operation of these centers through public-private partnerships, and (b) technical assistance to improve BRTA's capacity in vehicle inspection. Successful implementation of this component will help BRTA develop a national vehicle inspection program with additional VICs beyond the project and gradually remove unsafe and high GHG and pollution emission vehicles from its roads.

Component 4 will support Bangladesh in piloting an effective public-private partnership model to attract private investments in e-waste management infrastructure. This component will support (a) the development of a pilot e-waste management infrastructure through design-build-finance-operate arrangements to demonstrate technical, financial, environmental, and social feasibility of e-waste management and (b) technical assistance for proper operations of the new facility by promoting EPR schemes, formalizing value chains, and implementing related regulatory requirements. Successful piloting of this model will support its adoption in the development of other types of environmental infrastructure.

Appendix N. Estimation of Health Benefits of Interventions

The potential impact fraction (PIF) formula is applied to estimate the disease burden expected to be avoided by an intervention:

$$PIF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i^{'} RR_i}{\sum_{i=1}^{n} P_i RR_i} \qquad \text{(N.1)}$$

where P_i is the pre-intervention population distribution in relation to level of health-risk exposure, RR_i, and $P_i^{'}$ is the post-intervention population distribution in relation to RR_i.

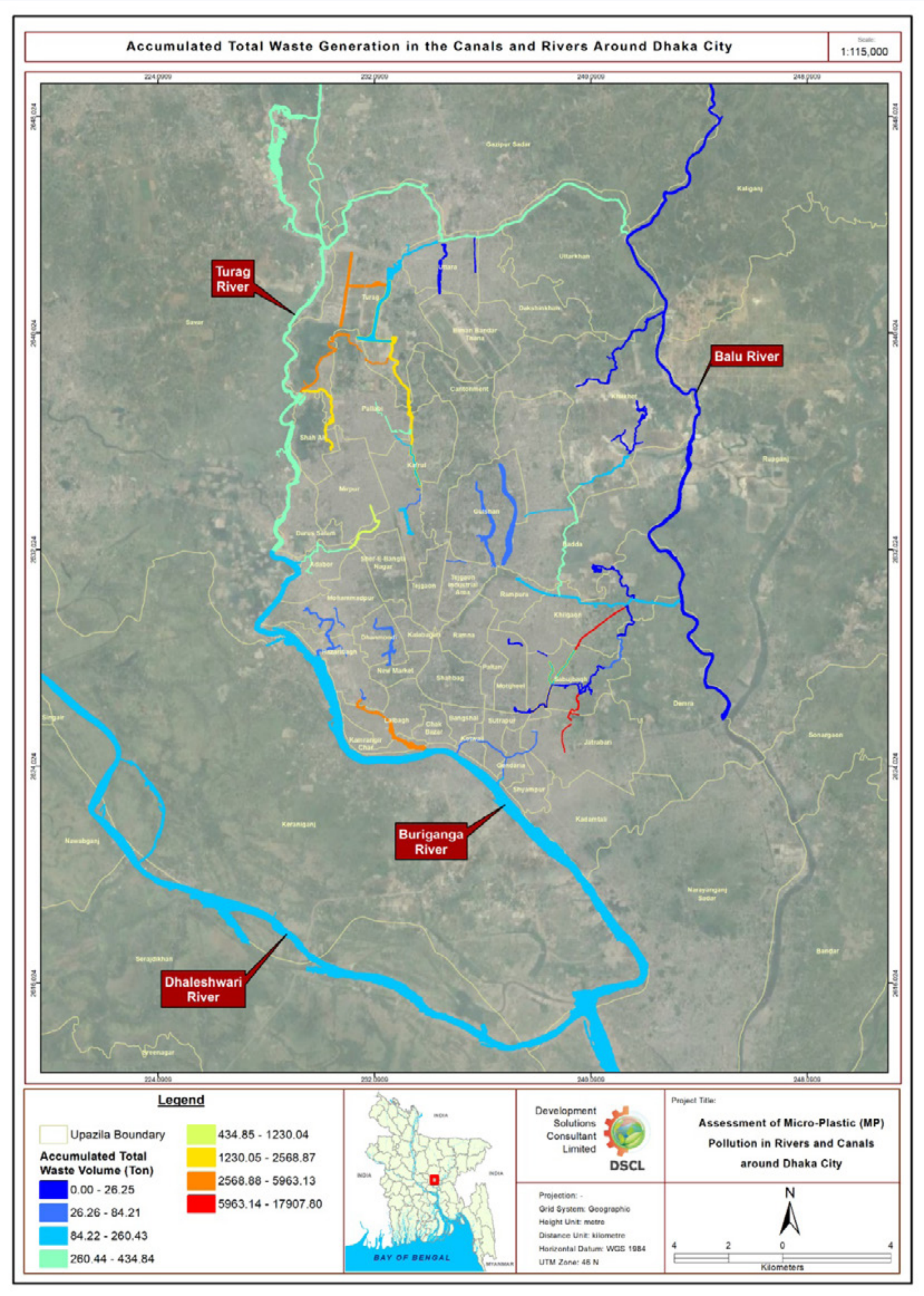
The avoided disease burden or health benefit (B) of interventions is then:

$$B = PIF * BDB \qquad \text{(N.2)}$$

where *B* is annual cases of mortality and morbidity prevented, *BDB* is the baseline disease burden or annual cases of mortality and morbidity in Bangladesh.

However, interventions are unlikely to instantaneously provide full health benefits for health outcomes that develop over long periods of exposure to pollution. This is the case for heart disease, stroke, chronic obstructive pulmonary disease (COPD), lung cancer, and diabetics associated with long-term $PM_{2.5}$ exposure, as well as for other noncommunicable diseases (NCDs) associated with long-term arsenic exposure. Therefore, it is assumed that reduced incidence of, and reduced deaths from, NCDs are gradually realized over ten years. However, for acute lower respiratory infections (ALRIs) from $PM_{2.5}$ exposure and inadequate handwashing, and diarrheal disease from microbiological pollution, full health benefits are realized in the same year that environmental improvements occur. Thus, over a 20-year period, annualized health benefits are 72 percent of full benefits for interventions addressing arsenic in drinking water, and 77 percent for $PM_{2.5}$ ambient air pollution (AAP) and $PM_{2.5}$ household air pollution (HAP), using a discount rate of 5 percent. Sanitation and hygiene health benefits are fully realized from the first year of interventions in the case of household drinking water.

Appendix O. Plastic Waste in Riparian Land and Waters of Rivers and Canals around Dhaka City



Source: World Bank 2023a.

Appendix P. Green Finance Roadmap for Green Growth in Bangladesh

An action plan, comprising a mix of policy choices spanning from institutional to regulatory components, is presented in tables P.1, P.2, and P.3 below. The plan offers guidance to promote the channeling of green finance to projects and activities related to green growth. The proposed actions allow for a gradual transition to a low-carbon and sustainable economy. To advance the financing of green growth in Bangladesh, the plan below identifies 27 priority actions (10 short-term, 11 medium-,term and 6 long-term) that the GoB can implement. These priority actions are listed along with their proposed implementers, beneficiaries, barriers to be addressed, and the extent (if any) to which these actions are already in place.

Table P.1 Short-term (1–2 year timeline) actions to facilitate financing of green growth in Bangladesh

Recommended action	Who could implement	Who benefits	Barrier addressed	Does it exist? Yes/No/ Partially
Intervention: Governance framework for green growth				
Set up system to track inflow of foreign resources and publicly disclose use of these funds to create trust in the capital market and to attract sustainable investors.	• Ministry of Finance (MoF), Bangladesh Bank (BB), Bangladesh Investment Development Authority (BIDA), Bangladesh Securities and Exchange Commission (BSEC), and others.	Investors	• Inadequate in-house technical capacity faced by FIs	Partially
Set up separate unit to evaluate green technologies, products, and services to provide technical assistance to evaluate their future potential.	• Ministry of Environment, Forest and Climate Change (MoEFCC) to lead, but it will also require the training of experts within the FIs.	FIs	• Inadequate in-house technical capacity faced by FIs. • Lack of project pipeline to attract foreign investment in green sectors.	No
Develop and approve the national green taxonomy (a framework for defining what can be called environmentally sustainable investments).	• MoEFCC and MoF.	Investors FIs Borrowers	• Inadequate expertise to evaluate green technologies and investments. • Lack of project pipeline to attract foreign investment in green sectors.	No
Intervention: Incentives				
BB and domestic banks reduce installment size and extend grace period to lessen fiscal burden on entrepreneurs seeking green finance loans.	• BB to take policy decisions to further rationalize loan-repayment tenure, reduce instalment size and grace period, and address other factors applicable to green finance transactions. • Commercial banks and FIs will implement policy decisions. • The above actions will increase banks and FIs' loan disbursements from their current level.	Borrowers	• Stringent requirements faced by borrowers.	No
Carry out further analysis to determine the right mix of fiscal incentives to address high-polluting industries, boost green markets, and attract private investments.	• MoEFCC with MoF.	Borrowers FIs Investors	• Low risk appetite. • Short-term focus.	Yes

Appendix P. Green Finance Roadmap for Green Growth in Bangladesh

Recommended action	Who could implement	Who benefits	Barrier addressed	Does it exist? Yes/No/ Partially
Adopt green guarantee scheme to minimize perceived risk to FIs (this is a credit-guarantee program to lessen lenders' risks in issuing green loans).	• BB to introduce a credit-guarantee scheme dedicated to green finance.	FIs Borrowers	• Low risk appetite. • Short-term focus. • Stringent requirements faced by borrowers.	Partially
Intervention: Capabilities				
Strengthen Sustainable Finance Units (SFUs) with skilled human resources to (a) evaluate green products, projects, and technologies more readily; and (b) monitor the different phases of implementation of projects and activities. These actions will reduce the perception of green-financing risk for banks.	• Banks to implement in their own offices. • BB to provide guidance on skills and certifications to be required for officials engaged in green financing operations.	Borrowers	• Inadequate in-house technical capacity faced by FIs.	Yes
Set up banking agents in outreach (remote, less accessible, underserved) areas to receive applications from entrepreneurs there to enable entrepreneurs in remote and less-accessible areas to access green finance.	• BB to take policy decisions to allow FIs to employ agent banking for receiving loan applications in outreach areas.	Borrowers Investors	• Limited knowledge and capacity to prepare bankable green projects faced by borrowers. • Lack of project pipeline to attract foreign investment in green sectors.	Partially
Establish a dedicated unit to help entrepreneurs overcome barriers to accessing finance.	• Small and Medium Enterprise (SME) Foundation to set up a dedicated unit within its institutional structure at its headquarters and at branches to help entrepreneurs have smooth access to green finance.	Borrowers	• Limited knowledge and capacity to prepare bankable green projects faced by borrowers.	No
Integrate carbon pricing into GoB's climate strategies.	• GoB to finance some of its environmental initiatives through decarbonization projects and carbon-pricing instruments.	Government Borrowers	• Lack of interagency coordination. • Lack of project pipeline to attract foreign investment in green sectors.	No

Source: World Bank.

Table P.2 Medium-term (2–3 year timeline) actions to facilitate financing of green growth in Bangladesh

Action	Who could implement	Who benefits	Barrier addressed	Does it exist?
Intervention: Governance framework for green growth				
Adopt national green growth strategy and a national action plan backed by appropriate combination of regulatory and institutional frameworks.	• MoF and MoEFCC to lead.	Government Borrowers FIs Investors	• Lack of interagency coordination.	No
Establish a national green finance strategy for greening the industrial and service sectors.	• MoF, MoEFCC, and Ministry of Industries (MoI) to lead, but BB, BSEC, and BIDA should be key participants.	Government Borrowers FIs Investors	• Lack of interagency coordination. • Lack of project pipeline to attract foreign investment in green sectors.	No
Constitute a high-level national oversight body to monitor progress in greening economic growth.	• MoF and MoEFCC to lead.	Government Borrowers FIs Investors	• Lack of interagency coordination. • Lax enforcement of laws against environmental offenders.	No
Engage local government bodies to have strong oversight to safeguard environmental and ecological services at the grassroots in local-level project development, planning, and implementation.	• Ministry of Local Government, Rural Development and Co-operatives with support of MoEFCC to lead in formulating policies to safeguard environment and ecological services at the grassroots.	Borrowers	• Lack of interagency coordination.	No
Internalize green accounting system and introduce green budgeting with a sound tracking system of resource allocation and expenditure for promoting inclusive green growth.	• MoF and MoEFCC to lead in introducing green budgeting.	Government Borrowers FIs Investors	• Lack of interagency coordination. • Lack of project pipeline to attract foreign investment in green sectors.	No
Adopt policy and strategy to establish a system for collecting point-source data to monitor pollution levels and contribute to the analysis by FIs.	• MoEFCC, Department of Environment (DoE), Aspire to Innovate (A2I) to lead.	Government FIs Borrowers Investors	• Lax enforcement of laws against environmental offenders. • Inadequate in-house technical capacity faced by FIs. • High cost of doing business.	Partially
Strengthen capacity for monitoring, reporting, and verification (MRV) to enable commercial lending institutions and BSEC to streamline the monitoring of green-finance impacts.	• MoEFCC, BB, and BSEC to lead in creating policies and practices that promote monitoring, reporting, and verification.	FIs Investors	• Inadequate in-house technical capacity faced by FIs. • Lack of project pipeline to attract foreign investment in green sectors. • High cost of doing business.	Partially
Intervention: Incentives				
Strengthen capital market to promote alternate financing by using innovative bonds.	• MoF, BB, and BSEC to lead in enabling a conducive atmosphere for green investment by using green and blue bonds.	Borrowers	• High capital investment.	Partially
Intervention: Capabilities				

Action	Who could implement	Who benefits	Barrier addressed	Does it exist?
Introduce information and communication technology (ICT)-based centralized system with borrowers' financial information to enable BB and lending agencies to have strong oversight of ESG and green finance impact.	• BB to institute a robust ICT-based setup in its Sustainable Finance Division. • Setup to include a network with banks and FIs to monitor environmental-safeguards compliance in every stage of project implementation including the business-operations phase.	FIs Investors Borrowers	• High cost of doing business for FIs. • Low risk appetite. • Short-term focus. • Stringent requirements faced by borrowers.	Partially
Provide training on sustainability and sustainable financing to civil servants within MoF, Planning Commission, city corporations, and so forth.	• Bangladesh Civil Service Administration Academy	Government Borrowers	• Inadequate expertise in government agencies to evaluate green technologies and investments.	Partially
Undertake national awareness-building campaign to promote green products and services among the consumers. These actions will contribute to achieving a national green growth vision.	• Relevant government ministries such as MoI, Ministry of Agriculture, MoEFCC, and Ministry of Information and Broadcasting to direct their subordinate agencies to pursue a nationwide campaign.	Consumers Borrowers	• Low demand for green products.	No

Source: World Bank.

Appendix P. Green Finance Roadmap for Green Growth in Bangladesh

Table P.3 Long-term (3–5 year timeline) actions to facilitate financing of green growth in Bangladesh

Actions	Who could implement	Who benefits	Barrier	Does it exist?
Intervention: Governance framework for green growth				
Introduce environmental management system (EMS) in SME sector to comply with international standards. These include the International Organization for Standardization's (ISO's) ISO 14000 (set of standards on environmental management) and ISO 9000 (set of standards for organizations to ensure they comply with regulation).	• MoI and SME Foundation to lead in introducing EMS in small and medium industries. • The new Industrial policy and Bangladesh export policy recognized the importance of motivating SMEs to introduce EMS and follow ISO guidelines. • This will, in the long run, expand opportunities for Bangladeshi products in international markets.	Borrowers FIs Investors	• Lack of capabilities to adopt and implement green practices and technologies. • High cost of doing business. • Inadequate expertise to evaluate green technologies and investments.	Partially
Intervention: Incentives				
Implement polluters pay principle through carbon and fossil-fuel taxes, and emission trading system. Tax, in the form of additional tax and VATs, goods and services produced by polluting industries.	• National Bureau of Revenue (NBR) to lead this action and to execute polluters pay principle with support of MoF, MoEFCC.	Borrowers Consumers	• Lax enforcement of laws against environmental offenders. • Low demand for green products.	No
Create green fund by using the resources from emission tax, pollution tax, and so forth. This fund to be leveraged with refinancing schemes to the advantage of small and medium entrepreneurs and to restore degraded natural ecosystems.	• MoEFCC and MoF to lead in setting up green fund with clear objectives for using these resources for green activities.	Borrowers	• Lax enforcement of laws against environmental offenders. • Low demand for green products.	No
Introduce cluster financing for shared technologies or practices adopted among related businesses. This will enable entrepreneurs to have enhanced access to finance.	• BB to introduce cluster financing scheme on a pilot basis. • Based on the success of the policy decision, this could be scaled up.	Borrowers	• High capital investment. • Stringent requirements faced by borrowers.	No
Establish green public procurement to boost demand for eco-certified products.	• Central Procurement Technical Unit (CPTU) under Planning Commission.	Borrowers	• Low demand for green products.	No
Intervention: Capabilities				
Prepare projects to access the Green Climate Fund (GCF) for resilience building of climate-vulnerable SMEs in coastal areas.	• SME Foundation, Palli Karma-Sahayak Foundation (PKSF), MoF, DoE, and BB.	Borrowers	• Lack of capabilities to adopt and implement green practices and technologies. • Limited knowledge and capacity to prepare bankable green projects.	Partially

Source: World Bank.

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