CLEAN AIR PLAN OF CAMBODIA

November, 2021

PREFACE

Air pollution is now standing one of the regional and global environmental challenges with the impacts is known to be unlimited. Its far-reaching impacts due to the distance of emission, the transboundary pollution, meteorological and geographical influencing outcome, air pollution has become a worthy of attention in terms of health concern. Sharing some similarities to other developing countries, a gradual increase in demand for mobility, power for products and households, infrastructure development and construction have led to the increase of emission in Cambodia.

Air pollution could not be considered as a local problem, but a reginal and global phenomenon which requires contribution from all parties. Moving forward in this direction, the ministry of Environment has come up with the Clean Air Plan of Cambodia (CAPC) as the national strategy document prescribing actions for reducing the air pollutants emission. This CAPC outlines some key aspects including air quality status, main air pollution sources, legal documents and management program for emission by sectors, as well as the mitigation measures.

CAPC has incorporated several measures for effective monitoring, assessment, and control of air pollution in Cambodia. In addition, the CAPC also addresses a number of challenges that have led to climate change due to emissions and are becoming a global trend in adopting the latest green technologies to reduce the air pollutants emissions that cause climate change. The development of CAPC is made through integration into the existing policies and programs of the Government of Cambodia which is a significant step towards identifying science-based policy decisions with regards to managing air quality. Thus, I do hope that the information in CAPC will serve as an important source of data and information, as well as an overview to support policy makers, planners, and researchers to work hard together in order to ensured sustainable development.

At last, I would like to express my high appreciation for efforts, comments and valued inputs through a participatory and collaboration approach from ministries/institutes of relevant sectors, research institutes and national and international organization to make CAPC the important national policy document happen and approve for the implementation from now on.

Phnom Penh, 30 November 2021

SAY SAMAL

Minister of Environment

ACKNOWLEDGEMENTS

At the very outset of this report, I would like to extend my sincere and heartfelt thanks to United Nations Environment Programme (UNEP) through Asia Pacific Clean Air Partnership (APCAP) for providing fund and technical support for the development of Clean Air Plan of Cambodia (CAPC).

I also would like express my profound thanks for Kakuko Nagatani-Yoshida and Bert Fabian from UNEP, Maria Katherina Patdu from APCAP, Chris Malley, Eleni Michalopoulou, Jessica Slater, Ryan Holmes from Department of Environment and Geography Stockholm Environment Institute, University of York of Sweden for providing technical support, data assessment and analysis and inputs for developing of CAPC, which is a crucial national policy document.

Meanwhile, I would like to thank to the Inter-ministerial Technical Working Group on Implementing of Conventions, Protocols and Agreements related to Environmental Protection, representatives of ministries/institution and relevant stakeholders for providing useful data, comments, review and inputs in the process of developing CAPC. At the same time, I would to express my appreciation to the Department of Air Quality and Noise Management of General Directorate of Environmental Protection of Ministry of Environment for their efforts in developing of CAPC successfully.

On behalf of the General Directorate of Environmental Protection, I would like to express my sincere thanks to **His Excellency SAY Samal**, Minister of Environment for his strong support and motivation in developing of CAPC.

At last, I hope the approval for the implementation of CAPC will contribute to reduce air pollution in Cambodia by implementing activities for protection of public health, environment and sustainable living.

Phnom Penh, 30 November 2021

CHEA SINA
Director General of Environmental Protection

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ACRONYMS

CCAC	Climate and Clean Air Coalition
CH4	Methane
CO_2	Carbon dioxide
EDC	Electricite Du Cambodge
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
Kg	Kilogram
Km	Kilometer
Km^2	Square kilometer
MT	Metric ton (tonne)
kWh	Kilo Watt Hour
LEAP-IBC	Long-Range Energy Alternatives Planning- Integrated Benefits Calculator
M	Meter
MAFF	Ministry of Agriculture, Forestry and Fisheries
MME	Ministry of Mines and Energy
MOE	Ministry of Environment
MOP	Ministry of Planning
MT	metric ton (tonne)
NDC	Nationally Determined Contribution
NH3	Ammonia
NIS	National Institute of Statistics
NMVOC	Non-Methane Volatile Organic Compound
NO_2	Nitrogen dioxide
NO_X	Nitrous Oxide
PM	Particulate Matter
SDG	Sustainable Development Goals
SEI	Stockholm Environment Institute
SLCPs	Short-Lived Climate Pollutants
SO_2	Sulphur dioxide
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compounds
WHO	World Health Organization
$\mu g/m^3$	microgram per cubic meter air

EXECUTIVE SUMMARY

The development of the Clean Air Plan of Cambodia is the first time that the emissions of key health-damaging air pollutants have been quantified nationally, and the reduction in air pollution from the implementation of mitigation measures that aim to improve air quality for the sake of environmental and public health protection have been quantified. In the document, the detail of pollutants is described based on their emission levels in Cambodia not only for historical years, but also their expected pathway trend in the future while the mitigation measures are exanimated.

The relevant data from the transport sector, agriculture, construction, energy consumption, waste and other related emission sources sectors are collected and with the assistance from the LEAP-IBC application, the current emission state of all major air pollutants such as nitrogen oxides, fine particulate matter, short-lived climate pollutants (black carbon and methane) and greenhouse gases (carbon dioxide) are quantified, as is their likely progression in the future.

In general, the largest sources of air pollutants and short-lived climate pollutants in Cambodia are transport, electricity generation, industrial process and residential sectors. Tracking to the source of specifically main air pollutants, it shows that residential sector is the largest source of PM2.5 and black carbon, following by charcoal making and transport. While the transport sector is highly contributed to emissions of nitrogen oxides (NO_x), carbon monoxide and carbon dioxide, the electricity generation is the second contributor of CO_2 following by industrial process sector. The main source of SO_2 is from electricity generation and Industry. The project of total emission illustrates that in 2030, PM2.5 will reach 98.5 Thousand MT, 14.6 Thousand MT (Black carbon), 70 Thousand MT (SO_2), 329 Thousand MT (NOx) and 40,150.8 Thousand MT (CO_2).

The several air pollutants and SLCPs have common sources, therefore designing mitigation strategies has the potential to lead to the simultaneous reduction of multiple pollutants, and also greenhouse gases like methane and carbon dioxide. The potential emissions reduction is examined with the implementation of key existing government regulations, policies and strategies related to emission reduction. To implement air pollution measures according to the circular no.01on "Measures to Prevent and Reduce the Ambient Air Pollution, the air pollutant emission can reduce dramatically. Especially, for PM2.5, PM10 and CO, where the implementation of the mitigation measures in the circular could cut emissions of these pollutants by halve in 2030 compared to a baseline scenario. For all measures combined, air pollutant emission is cut significantly over the next 9 years compared to a baseline scenario, with a reduction in emissions in 2030 of 59.8 Thousand MT (60.71%) for PM2.5, 73 Thousand MT (55.1%) for PM10, 9.3 Thousand MT (63.69%) for Black Carbon, 36.5 Thousand MT (52.14%) for SO_2, 158 Thousand MT (48.02%) for NO2 and 7,461.7 Thousand MT (18.58%) for CO2.

1. INTRODUCTION

The Kingdom of Cambodia is located in the southwest of the Indochinese peninsular and has a rich culture that dates back 2,000 years ago. The country has a land area of 181,035 square kilometers and population of 16 million people (2017). Like in the rest of Southeast Asia, Cambodia's climate is characterized by two main seasons: the monsoon, which brings rain from mid-May to October, and dry season from November to April. Cambodia is recognized as a country with rich natural and cultural resources. Environment and natural resources are the foundation of economic, social, cultural and well-being of the Cambodian people.

Economically, Cambodia has enjoyed strong growth rates during the past decade. Economic performance had positive statistics with an average Gross Domestic Product (GDP) growth of 6.98% between 2010-2015, and 7.1% from 2015-2019 (Cambodia Economic Update, World Bank (WB). 2019). GDP per capita is US$1,641 in 2019 (WB, 2019) compared to approximately US$1,215 in 2016 (MEF, 2016). With its rapidly growing economy, Cambodia is not immune to rapidly rising air pollution levels. Urban Cambodians, in particular, have observed a deterioration in the quality of the air they breathe and rural Cambodians are not immune to breathing high levels of air pollutions, especially the 80% of rural population who continue to rely on wood for cooking. Increasing industrial processes; a growing fuel-intensive vehicle fleet; wildfires, open field burning of solid waste, and construction sites, are seen as the main contributors to this decline in air quality.

Scientifically, air pollution causes a series of significant health problems especially on respiratory system and premature death. Air pollution and climate change are also closely related. Carbon dioxide and the short-lived climate-forcing pollutants (SLCPs) have significant impact on the climate. Improving air quality would benefit the climate and foster sustainable development through delivering better health outcomes, preventing crop losses, and preventing the climate from reaching tipping points that can aggravate long-term climate impacts and make adapting to climate change more challenging.

Cambodia has an opportunity to curb the trend of rising air pollution. To do this, significant effort in monitoring, enforcement of Cambodia's ambitious and innovative new air quality regulation is needed. Additional priority mitigation measures could also be identified to complement existing air quality regulations and help achieve national ambient air quality standards. Within the effort to reduce air pollution in Cambodia, the nation received financial and technical support from the United Nations Environment Programme (UNEP)'s Asia Pacific Clean Air Partnership (APCAP) and the Climate and Clean Air Coalition (CCAC) to develop an important strategic document tilted "Clean Air Plan of Cambodia". This important document will contain information and action plans related air pollution control in Cambodia, such as instructional framework, sources of air pollution, emissions projection and especially, priority emission mitigation measures.

1.1 Air Quality Management in Cambodia

Air pollution causes a series of significant adverse impacts to public health, environment, and the economic development. Although effects are experienced locally, air pollution is also a transboundary problem: while most air pollutants, for example oxides of nitrogen, directly impact air quality proximate to their emission source, other pollutants such as Sulphur dioxide can also travel long distances to affect air quality hundreds or even thousands of kilometers away.

Since 2000, the Government of Cambodia began to address air and noise pollution at the national level with the Sub-decree No. 42 on Air Pollution Control and Noise Disturbance. The Sub-decree outlines the general purpose which is to "*protect the quality of the environment and public health from air pollution… through monitoring, curbing and mitigation activities*." Table 1.1 provides an overview of the existing framework for air quality management in Cambodia.

The Department of Air Quality and Noise Management (DAQNM) under the supervision of the General Directorate of Environmental Protection of the Ministry of Environment of Cambodia is the main government agency assigned in monitoring and controlling air pollution from all sources (area, stationary, and mobile sources). The DAQNM's mandate is to develop policies, strategies, regulations, and action plans to prevent air pollution and improve the air quality for public health and environment protection. Moreover, DAQNM has duties to control emissions from stationary sources, such as factories, to ensure the emissions from pollution sources are in compliance with the national emission standard. Part of the responsibilities of the DAQNM is to study, research, evaluate, and disseminate new and emerging technology on monitoring, prevention, and control of air pollutant emissions, noise, or vibration from mobile and stationary sources and to act as the focal institution/partner to implement the international/regional conventions, protocols and agreements related to air pollution.

Table 1.1 The existing framework for air quality management in Cambodia

Name of Policy/Measures	Type of Policy/Measures	Year went into implementation/adopt	Related Air Quality / 25 Clean Air Measure1
Constitution of the Kingdon of Cambodia	National Constitution	1993	The state shall protect the environment, water, air,..
Law on Environmental Protection and Natural Resource Management	Law	1996	Protection the water, land, air,..
Sub-decree on Environmental Impact Assessment Process	Regulation	1999	Managing environmental pollution from investment projects
Sub-decree on Water Pollutioin Control	Regulation	1999	Stop biogas leakage from wastewaater treatment
Sub-decree on the Control of Air Pollution and Noise Disturbance	Regulation	2000	Strengthen industrial process emission standards, air quality standard
Sub-decree on Solid Waste Management	Regulation	1999, amended 2015	Improve solid waste management
Sub-decree on Management of Garbage and Solid Waste of Urban Areas	Regulation	2015	Improve solid waste management
Regulation on General Conditions for Connecting Solar PV Generation Sources to the Electricity Supply System of National Grid	Regualtion	2018	Promote renewable electricity generation
National Implementation Plan for Management of Persistent Organic Pollutants	Strategic Plan	2006	Strictly enforce ban on household waste burning

Climate Change Strategic Plan 2014-2023	Strategic Plan	2013	Provide incentives for improved energy efficiency in households
National Strategic Plan for Climate Change Adaptation and Greenhouse Gas Mitigation in Transport	Strategic Plan	2013	Regularly maintain and inspect vehicles
National Strategic Plan on Green Growth 2013-2030	Strategic Plan	2013	Clean energy promotion
National Policy, Stretegy and Action Plan on Energy Efficiency	Strategic Plan	2013	Improve energy efficiency for industry
National Determined Contribution (UNFCCC)	Strategic Plan	2015	Clean cooking and heating, provide better mobility options, mainstream electric vehicles
Blue Mobility	Strategic Plan	2015	Mainstream electric vehicles
National Environmental Strategy and Action Plan 2016-2023	Strategic Plan	2016	Strengthen industrial process emissions standards
Cambodia National REDD+ Strategy 2017-2026	Strategy Plan	2017	Prevention of forest and peatland fires
Green City Strategic Plan for Phnom Penh	Strategic Plan	2017	Promote renewable electricity generation, incentives for improved energy efficiency in households
Deika on Solid Waste Management in Battambang	Strategic Plan	2017	Improve solid waste management, strictly enforce bans on household waste burning

Phnom Penh Sustainable City Plan 2018-2030	Strategic Plan	2018	Strengthen emission standards for road vehicles, Promote renewable electricity generation
Phnom Penh Waste Management Strategy and Action Plan 2018-2035	Strategic Plan	2018	Improve solid waste management
Circular on Measures to Prevent and Reduce the Ambient Air Pollution	Strategic Plan	2020	new ambient air quality standards for PM10, and PM2.5, emissions standards for vehicles, and a fuel quality standard
Cambodia's Updated Nationally Determined Contribution	Strategic Plan	2020	Emission reduction measurement, renewable energy
Implementation of technical guidelines on air pollution control from industrial enterprises	Circular	2018	Technical guidelines for the control and prevention of air pollution from stationary sources and emissions standards
Implementation of Air Quality Index to Calculate Air Pollution Data in the Kingdom of Cambodia	Circular	2020	Determine and implement air quality index

1.2 Health Impacts from Air Pollution

Air pollution has no boundary and the exposure to air pollutants, both short- and long-term exposure, can affect human health. Particulate matter (PM) containing a complex mixture of organic and inorganic particles suspended in the air which the major components are sulphates, nitrates, ammonia, black carbon etc. Particles with the diameter of 2.5 µm or less are the most health-damaging as it can penetrate and lodge deep inside the lungs. There are some diseases associated with long-term exposure to PM such as adverse birth outcomes, childhood respiratory disease, diabetes, atherosclerosis, and neurodevelopment and cognitive function. It is reported by World Health Organization (WHO) that about 91% of people globally breathe air that exceed the WHO Air Quality Guidelines (Table 1.2) and that ambient air pollution has killed about 4.2 million people annually worldwide where Western Pacific and South East Asia are the most affected (WHO, 2016).

Table 1.2 WHO Air Quality Guideline (WHO, 2006)

Pollutant	NO_2(µg/m³)	SO_x(µg/m³)	PM2.5(µg/m³)	PM10(µg/m³)	O_3(µg/m³)
Annually	40	-	10	20	-
24 hours	-	20	25	50	-
8 hours	-	-	-	-	100
1 hour	200	-	-	-	-

Differences variety of air pollution sources associated with different types of health effects. There are several studies including Toxicological, Epidemiological, Clinical, Toxicological studies regarding to on health impact due to air pollutants has been conducted and there were evidences on effect of pollutants and diseases associated.

Table 1.3 Pollutants exposure and health impact

Pollutants	Exposure	Impact
PM2.5	short-term	mortality and morbidity
	long-term	- lung cancer - mortality and morbidity - cardiovascular mortality and morbidity, - several health outcomes: atherosclerosis - adverse birth outcomes and childhood respiratory disease
PM10		- mortality, morbidity (both, short-term and long-term) - cardiovascular diseases, including ischemic heart disease, cerebrovascular disease and heart failure associated
NO_2	long-term	- respiratory and cardiovascular mortality - respiratory symptoms and lung function in children
	short-term	- respiratory outcome
SO_2		- effect on heart rate variability - asthma symptoms in children - respiratory symptoms and lung function in children - chronic obstructive pulmonary disease - mortality and morbidity risk
O3		premature mortality and non-fatal respiratory diseases

1.3 Benefits of Air pollution Mitigation

The emissions of pollutants to the atmosphere can cause a variety of adverse impacts including human health, climate, and environmental impacts. Air pollution reduction has been identified as a global health priority which has been reflected in the sustainable development goal (SDG) as following: urban sustainable development as SDG 11 indicates air pollution levels in cities, sustainable energy as SDG 7 indicates the access to clean energy), health as SDG 3 indicates reduction of mortality due to air pollution (WHO, 2016). Thus, mitigation for emission reduction is significant and in general, the implementation of these mitigation measures can also contribute to sustainable development benefits.

a) Poverty

Pollution is strongly linked to poverty and the vulnerable populations are always the first to be impacted and those impacts give the vulnerable populations a critical time to adapt. Being in a good health make people spend less on medical expense, and at the same time increase productivity. Emission reduction contribute to decrease the rate of global warming, lessen the environmental shocks, disasters, crop lost.

b) Zero Hunger

Air pollution affect not only on health, but also a major cause on crop damage and affect food quality and security. According to the UNEP/WMO assessment, with the implementation of SLCPs emission mitigation, the loss of 52 million tons of four staple crops: maize, rice, soybean and wheat will be avoided globally through actions on methane and black carbon air pollution.

c) Good Health and Well-Being

The pollutants from air pollution emission has a closely link to diseases including cancer, respiratory infection and cardiovascular disease. The pollutants increase in population morbidity and mortality. The implementation of mitigation measure will help reduce use of diesel powered vehicles resulting in the reduction of black carbon emissions, promote public transport, clean energy. Fresh air provides the families not only with physical health, but also emotional health.

d) Clean Water and Sanitation

Air pollution can place water at risk. Harmful acid rain produced by pollutants such SO_2 and NO_x from open burning and the combustion of fossil fuels mix with precipitation can lower water quality that make the water unsafe for consumption.

e) Climate Action

Fuel combustion play a main role in climate change, which put food, air and water supplies at risk, and cause a major threat to human health. With the mitigation measures, greenhouse gas will be reduced through the control of fuel quality, avoid open burning, improvement of transportation, use clean energy.

f) Life Below Water

Accumulation and deposition of air pollutants, for example acid rain, on water may cause negative effect to quality and life under water. It may lead to eutrophication and acidification of fresh water bodies and accumulation of toxic metals and other pollutants in water, as well as aquaculture.

1.4 Objective of Developing the Clean Air Plan of Cambodia

The purpose of the Clean Air Plan of Cambodia is to outline a set of priority policies and measures to reduce the key sources of air pollution in the country and lead to improvement of air quality levels for public health protection. It also identifies the effectiveness of the planned and proposed mitigation measures to reduce air pollution emissions. This Clean Air Plan builds on existing plans and strategies in the Cambodia including the Air Pollution Circular #01 (Measures to Prevent and Reduce the Ambient Air Pollution), and other relevant plan that that include mitigation measures (that can affect air pollution emissions), but for which the air pollution emission reduction potential has not yet been evaluated.

The priority mitigation measures identified in this plan are aligned and complementary to the Air Pollution Circular mitigation measures. In addition, the Clean Air Plan proposes additional measures relevant for the Cambodia based on the recommended 25 clean air measures from the UNEP and CCAC 2018 Report "Air Pollution in Asia Pacific: Science-Based Solutions."

The overall objectives of the Plan and the planning process are:

- To develop an integrated analysis of air pollutants, greenhouse gases and short-lived climate pollutants to identify the major sources sectors of air pollutants currently, and how they are likely to change in the future.
- To identify mitigation measures in existing plans and strategies that will be effective at reducing air pollution emissions while simultaneously mitigating greenhouse gas emissions.
- To identify additional mitigation measures that could be taken to further reduce air pollution emissions.
- To quantify the multiple benefits of the identified mitigation measures for improving air quality and mitigating climate change.
- To identify possible ways to further mainstream action on air and climate pollutants into existing planning processes.
- To prioritize action and pave the way for coordinated air quality management.
- To encourage planned implementation of existing plans and in creating new action in different sectors.

1.5 Methodology for Developing the National Clean Air Plan

An integrated emissions and scenario analysis for air pollutants, greenhouse gases and short-lived climate pollutants estimates the current and future national trends in air quality. Followed by the air pollution, GHG and SLCP emission reductions could result from the full implementation of the identified air pollution mitigation measures. Finally, specific actions to increase implementation of these air pollution mitigation measures are identified, as well as actions to improve air quality management in general in Cambodia.

To develop the Clean Action Plan of Cambodia, it is necessary to develop quantitative analysis of air pollution in Cambodia to identify current sources, and to evaluate the effect of the different mitigation measures included in the plan. Therefore, the LEAP (Low Emissions Analysis Platform) and its Integrated Benefits Calculator (IBC) or in short LEAP-IBC developed by the Stockholm Environment Institute (SEI) that has been used for energy planning and greenhouse gas and air pollution mitigation assessments was utilized. In addition, because of the range of sources that emit pollutants in Cambodia, a wide range of stakeholders was engaged and consulted in the development of this plan.

1.6 Stakeholder Engagement

The Plan was developed by a *technical working group* established in December 2020 on a decision of the Ministry of Environment in charge of developing and executing the mitigation measures. The technical working group comprises of representatives from inter-ministerial agencies, academic institutes, and other relevant sectors. The members of the technical working group coming from relevant line ministries and research academia such as Ministry of Environment, Ministry of Industry Science Technology and Innovation, Ministry Mine and Energy, Ministry of Public Work and Transportation, Ministry of Agriculture, Forestry and Fishery, Ministry of Interior, Ministry of Education Youth and Sports, Ministry of Foreign Affairs and International Cooperation, Ministry of Water Resources and Meteorology, Ministry of Information, Ministry of Labor and Vocational Training, Ministry of Health, Ministry of Commerce, General Department of Customs and Excise, Council Development of Cambodia, Royal University of Phnom Penh and Institute of Technology of Cambodia. The terms of reference for the working group is provided as Annex 1.

1.7 Challenges identified during the formulation of the Clean Air Plan

The following challenges were identified during the development of this plan:

- Limited data on pollutant sources, emissions and levels of air quality to subsequently identify measures to mitigate concentrations. Therefore, international default data in air pollution emission factors were employed in the absence of certain local data.
- Lack of human resources and technical expertise within the government with regards to air quality management.
- Difficulty in securing commitment from stakeholders in developing and implementing new actions for the Plan. Even though air quality management is a crosscutting issue, many stakeholders do not see the benefits of air quality in contributing towards their development goals. (Formulation of new actions without support may also lead to an absence of ownership by the lead stakeholders. This would hinder the Plan from being adopted and implemented.)

2. STATUS OF AIR QUALITY AND SOURCES OF EMISSIONS

This chapter describes the state of air quality in the country. It discusses the pollutants in detail, including the magnitude of emissions of different pollutants in the Cambodia currently, and their likely progression into the future. The major sources sectors of emissions of each pollutant in the Cambodia such as residential, transport, waste, agriculture, and electricity generation are also identified.

2.1 Status of Air Quality in Cambodia

Table 2.1 Overview of air quality status in Cambodia

Status of Air Quality In Cambodia, as in other countries, economic development is certainly leading to increase the level of air pollution. The concentration of PM2.5, SO_X, NO_X, CO, CO_2, O_3, TSP and other substances are emitted from various sources such as vehicle, motorbike, factories, generators, etc.
Air Quality Monitoring Air quality monitoring has been in place since 1999 and from 2017 air quality have been further strengthen by installing the first equipment for PM2.5 monitor in Phnom Penh. Later, in 2018, air quality monitoring were installed in Phnom Penh and other provinces. For monitoring the current air quality, so far, the DAQNM has installed 44 units of low-cost air quality monitoring equipment across the provinces of Cambodia. The equipment mainly monitors key parameters including PM2.5, PM10, CO, NO_2, SO_2 and O_3. The data from the air quality monitoring equipment have been recorded and daily posted in MOE Facebook page and LED Screen in front of the MOE building in Phnom Penh. Air Quality Index (AQI) is developed to better communicate with the public. AQI results for stations throughout the country have been published daily through the social media page of the Ministry of Environment. For better management of air pollution sources, MoE was provided with the first mobile air quality monitoring vehicle with which 16 parameters and positive inert particles with the diameter of 1 micrometer can be detected. This mobile air quality monitor was inaugurated in 2020.

Air Quality Data

Generally, in many cities, there is no noticeable variation in concentration of monitoring parameters except PM2.5. In Phnom Penh, the average annually concentration of PM2.5 in Phnom Penh keep increasing (13.59 µg/m³ in 2017, 19.26 µg/m³ in 2018) and it came in with an average annually reading of 21.12 µg/m³ in 2019. However, the reading is still complying with the standard (25 µg/m³), but above the WHO air quality guideline for particulate matter. Due to the climate and the cycle of the seasons, in certain months of the year the quantity of PM in the air is significantly higher in the dry season. As for PM2.5, it is observed that the concentration is generally high in region with high forest cover.

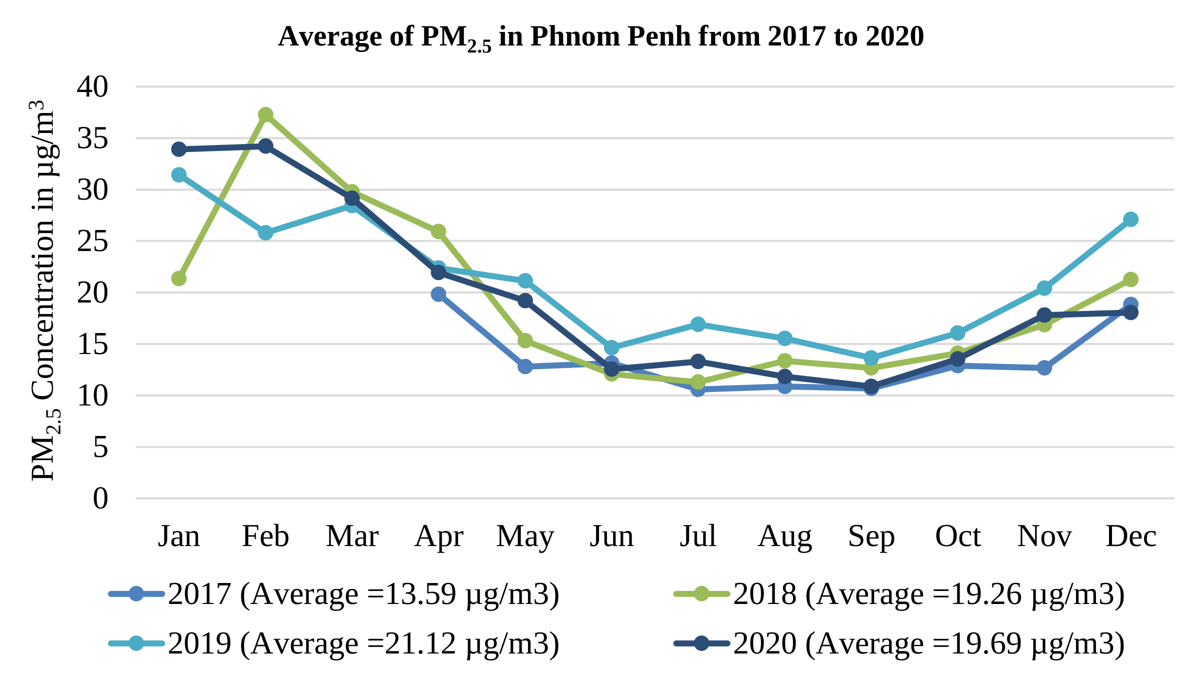

Figure 2.1 Graph of average of PM2.5 in Phnom Penh City from 2017 to 2020

Reporting of AQ information

The data from the air quality monitoring equipment have been recorded and daily posted in MOE Facebook page and LED Screen in front of the MOE building. Air Quality Index (AQI) is developed to better communicate with the public. AQI results for stations throughout the country have been published daily through the social media page of the Ministry of Environment.

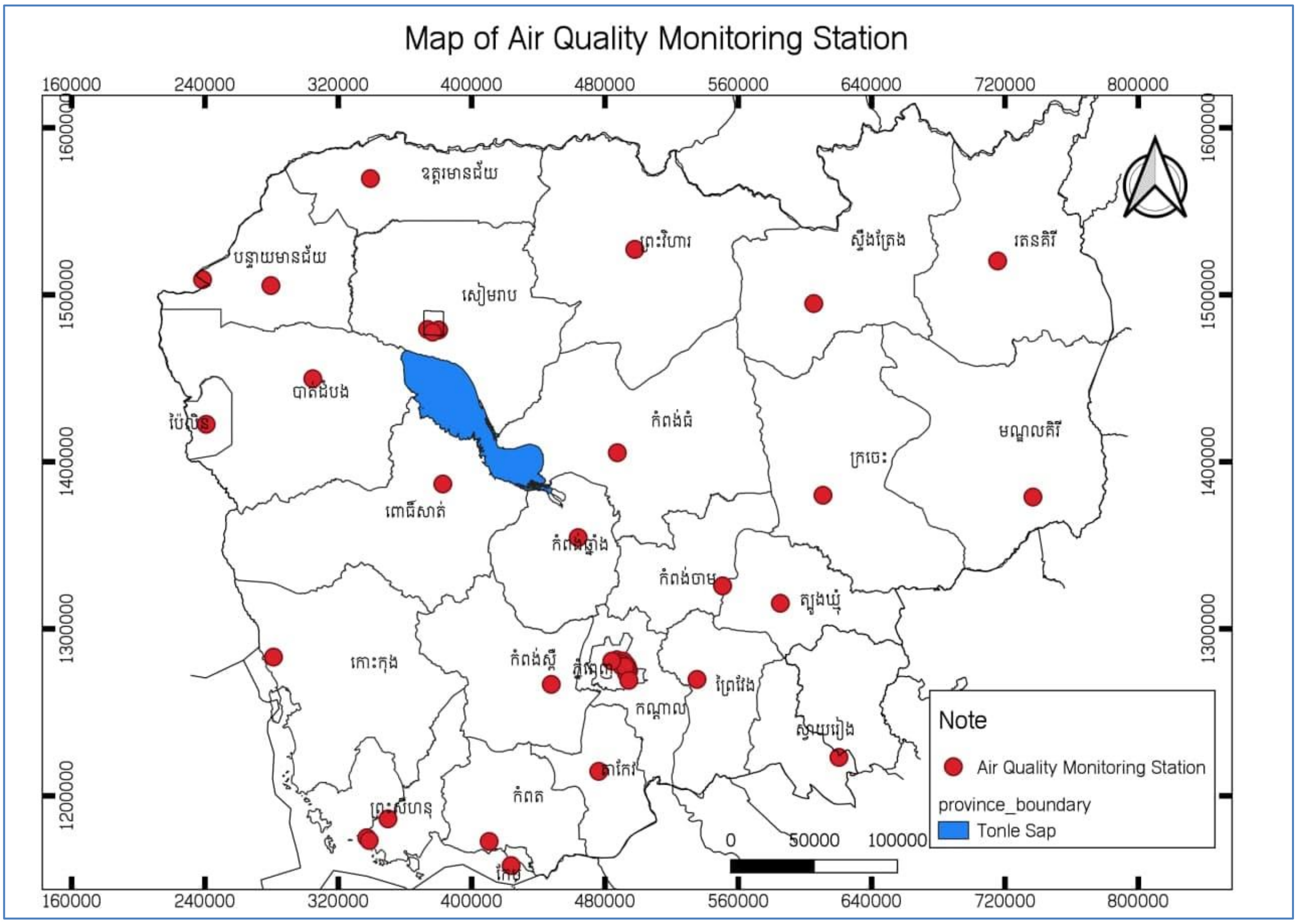

Figure 2.2 Map of Air Quality Monitoring Station

2.2 National Total Emission

The levels of air pollution in the atmosphere are determined by i) the emissions of air pollutants from different sources in Cambodia, ii) weather patterns that disperse and transport air pollutants from one location to another, and iii) emissions of air pollutants in other countries that are transported to Cambodia. This Clean Air Action Plan of Cambodia focuses on assessing the emissions of air pollutants that occur within Cambodia, as it is those sources within the country that it is possible to take action and implement mitigation measures to reduce the magnitude of air pollutant emissions, and improve air quality for Cambodians.

National total emissions were estimated from all major energy and non-energy sectors for the Cambodia for all major air pollutants (nitrogen oxides, volatile organic compounds, ammonia, fine particulate matter (PM2.5), organic carbon and carbon monoxide), short-lived climate pollutants (black carbon and methane), and greenhouse gases (carbon dioxide). More information on these individual air pollutants is included in Section 2.3. Table 2.2 displays how the national emissions of these pollutants were projected to progress over the years from 2010 until 2030 under a baseline scenario taking into account future projections of population and economic growth in Cambodia. Table 2.3 shows, for the base year 2010, the pollutant emissions split by major source sectors.

Table 2.2 Total emissions from 2010 to 2030

Baseline: (Thousand MT), Summary											
	Organic Carbon	**Black Carbon**	**PM2.5**	**PM10**	**Ammonia**	**Sulfur-Dioxide**	**Nitrogen-Oxide**	**Non-Methane Volatile Organic Compounds**	**Methane**	**Carbon Monoxide**	**Carbon Dioxide**
2010	28.69	7.21	61.44	74.03	138.08	63.71	83.57	346.38	347.36	978.49	9,161.76
2015	31.85	8.46	68.14	83.85	124.91	32.93	127.03	462.16	304.39	1,234.18	13,608.09
2020	34.04	9.35	72.88	92.50	114.04	40.97	158.00	578.95	260.26	1,492.55	18,444.60
2025	38.58	11.37	83.33	107.85	109.95	52.18	221.38	778.54	234.10	1,952.94	26,438.60
2030	44.97	14.57	98.50	132.42	112.00	70.05	328.96	1,119.21	218.22	2,725.61	40,150.82

Table 2.3 National total emission of air pollutants, short-lived climate pollutants and greenhouse gases in 2015 in the Cambodia by sector (Thousand MT).

Branches	**Organic Carbon**	**Black Carbon**	**PM2.5**	**PM10**	**Ammonia**	**Sulfur-Dioxide**	**Nitrogen-Oxide**	**Non-Methane Volatile Organic Compounds**	**Methane**	**Carbon Monoxide**	**Carbon Dioxide**
Residential	12.726	3.842	29.325	36.539	3.972	3.631	9.917	117.983	22.163	371.972	14.891
Commercial and Public Services	0.001	0.002	0.004	0.005	0.001	0.297	0.113	0.020	0.005	0.039	59.439
Industry	0.975	0.567	1.980	2.024	0.004	2.658	3.652	4.084	0.411	8.259	402.524
Agriculture	0.045	0.064	0.153	0.153	0.000	0.037	1.499	0.080	0.005	0.207	117.892
Energy Industry Own Use	0.000	0.000	0.001	0.002	0.000	0.015	0.044	0.001	0.002	0.011	49.450
Transport	2.295	1.868	6.151	6.151	0.188	2.398	90.485	189.469	2.084	437.511	8233.438
Electricity Generation	0.010	0.008	0.192	0.397	0.009	20.756	10.200	0.063	0.050	0.394	4043.851
Charcoal Making	4.151	0.611	8.366	8.366	1.191	1.852	0.579	105.544	43.119	311.483	-
Industrial Process Emissions	-	0.001	0.218	0.370	-	0.153	0.077	0.153	-	0.421	686.601
Agriculture (Non-Energy)	1.742	0.264	2.886	3.044	117.434	0.190	1.249	2.296	229.671	32.478	-
Waste	9.904	1.229	18.423	22.361	2.106	0.941	9.215	42.467	6.879	71.401	-
Construction	-	-	0.444	4.442	-	-	-	-	-	-	-

In general, the largest sources of air pollutants and short-lived climate pollutants in the Cambodia are the transport, industry, residential and waste sectors, and electricity generation, industrial process emissions and charcoal making also contribute the pollution for some specific pollutants e.g. PM2.5, SO_2, NO_x, and greenhouse gases like CO_2. This shows that several air pollutants and SLCPs have common sources, therefore designing mitigation strategies has the potential to lead to the simultaneous reduction of multiple pollutants, and also greenhouse gases like methane and carbon dioxide. Between now and 2030, emissions of key pollutants are expected to increase substantially if policy measures to reduce emissions are not implemented (under baseline scenario), due to the growth of population and the Gross Domestic Product (GDP).

The following sections describe in detail the major sources, and future projections of each air pollutant and SLCPs.

2.3 Air Pollution

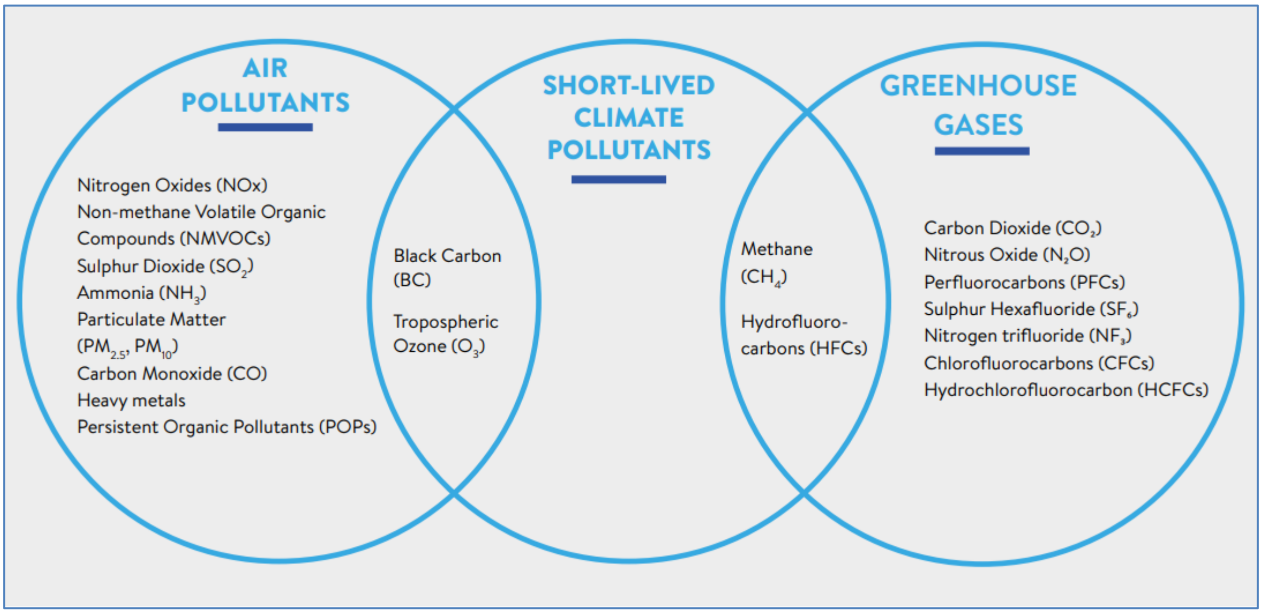

Figure 2.3 Summary of pollutants that are classified as air pollutants, short-lived climate pollutants and greenhouse gases (Source: CCAC SNAP, 2019)

2.3.1 Particulate Matter

The classification of particles in air by size and composition are known as particulate matter or PM. It is not a single pollutant, but made of multiple components and is produced from emissions from multiple emission sources. The different sizes of aerosols are:

- Total Suspended Particles or TSP (aerodynamic diameter < 30 µm)
- PM10 or course particulate matter (aerodynamic diameter < 10 µm)
- PM2.5 or fine particulate matter (aerodynamic diameter < 2.5 µm)

The PM size affects its lifetime in the atmosphere, distribution, and indoor-outdoor ratio. PM2.5 is extremely harmful to human health at high levels of short-term exposure and from prolonged exposure even to low concentrations.

In 2015, the total emission of PM2.5 in Cambodia was about 68.14 Thousand MT. The Residential sector dominated the share of about 43.03% and followed by 27.04% from Waste, 12.28% from Charcoal Making, 9.03% from transport, 2.91% from industry, and other sources merged only about 5.72%), Figure 2.4. The main reason that causes the PM2.5 have a highest share because number of people living in rural area (about 80%) use wood as fuel for cooking stove. Emissions from charcoal making comes from open waste burning.

Figure 2.5 below shows the trend in emissions by their source sectors between 2010 and 2030 under the baseline scenario. Under baseline scenario, PM2.5 emissions are projected to increase about 37.63 percent by 2030.

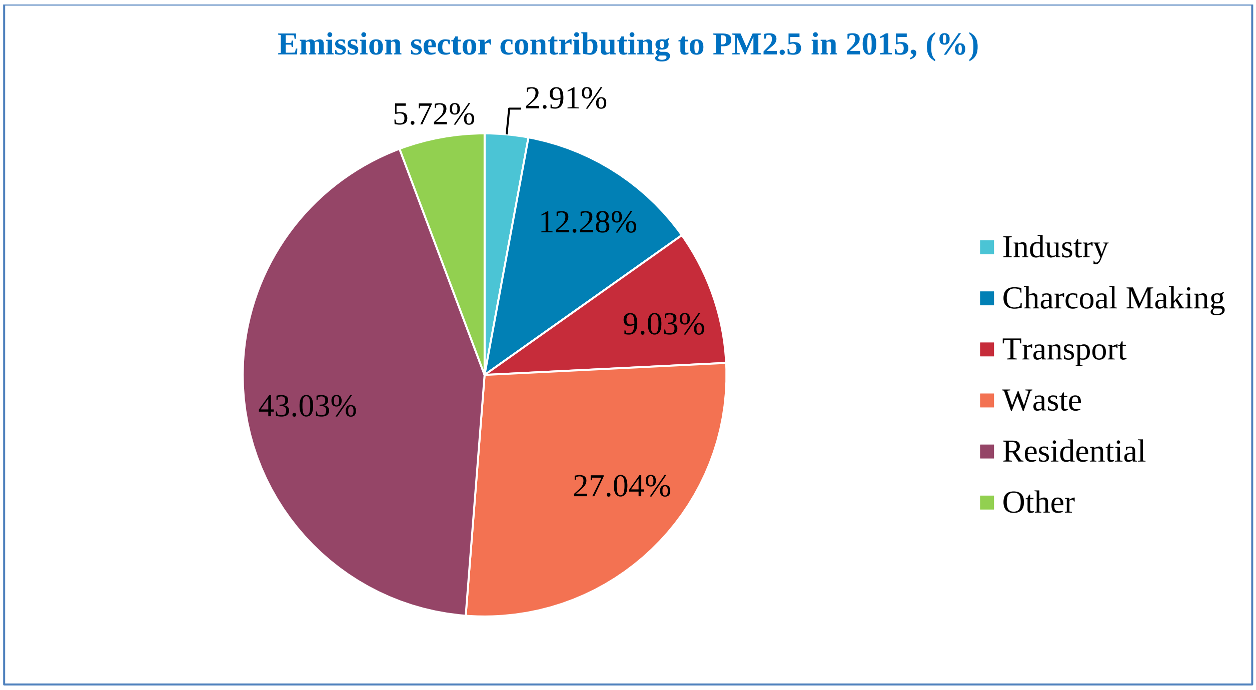

Figure 2.4 Share of PM2.5 emissions by sector in 2015

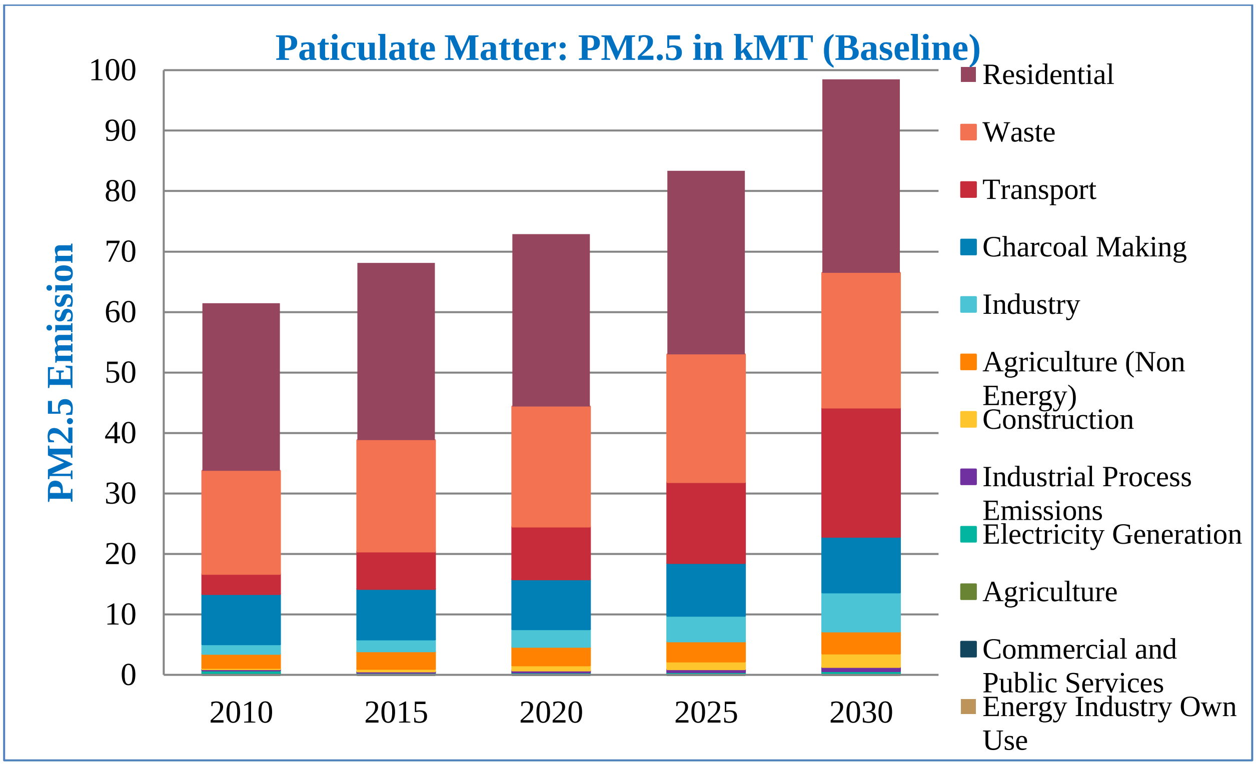

Figure 2.5 Total PM2.5 Emission in Cambodia between 2010 and 2030

In 2030, the largest emission source of direct PM2.5 emissions is still projected to come from the residential sector (wood burning mostly from rural areas) with the total emission of 98.5

Thousand TM. Direct emissions of PM2.5 from the residential sector come from cook stove that use charcoal and wood in rural areas of Cambodia.

2.3.2 Sulfur Dioxide (SO_2)

SO_2 is a colorless gas that easy to dissolve in water droplet to form sulfuric acid and later developed to be acid rain. It has been known as a potential pollutant which can damage building, reduce crop production, and harmful to human health as well as the natural ecosystem. SO_2 is primarily produced when burning fossil fuel in power plants, charcoal transformation, combustion in vehicle engine and other source sector which activities consumed fuel oils.

The figure 2.6 is show that electricity generation is main SO_2 emissions contributor responsible for about 64.88% in 2015, and residential (11.35%), industry (8.31%), transport (7.50%), charcoal making (5.79%), and the remaining 2.17% were from combined sources (waste, Commercial and Public Services, Agriculture (Non-Energy), Industrial Process Emissions, Agriculture, and Energy Industry Own Use).

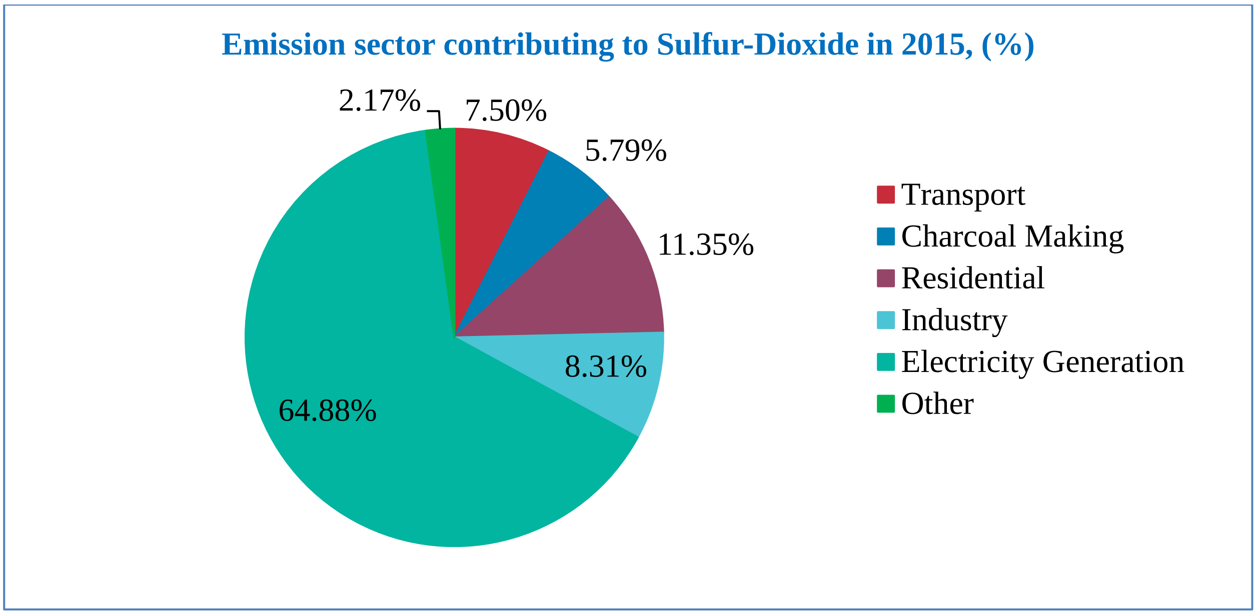

Figure 2.6 Share of Sulphur Dioxide emission by sector in 2015

The total emission of SO_2 from 2010-2030, Figure 2.7, were declined due to the reduction of fuel-based electricity generation in relation to the increase of coal thermal power plant. As of 2010, the total emission was about 63.71 Thousand MT and dropped to about 32.93 Thousand MT in 2015, the estimated decrease rate was about 8.2% per year. SO_2 emission in 2015 from electricity generation reduced by two times from 62.85 Thousand MT in 2010 to about 32 Thousand MT in 2015, it is caused by the changing fuel consumption in electricity generation from heavy fuel oil to sub bituminous coal. Similar trend was observed in the industry sector. Nevertheless, an increasing trend start from 2015 to 2030 of SO_2 emissions were applied to electricity generation, transport, residential and charcoal making, which the total SO_2 reaches 70 Thousand TM in 2030.

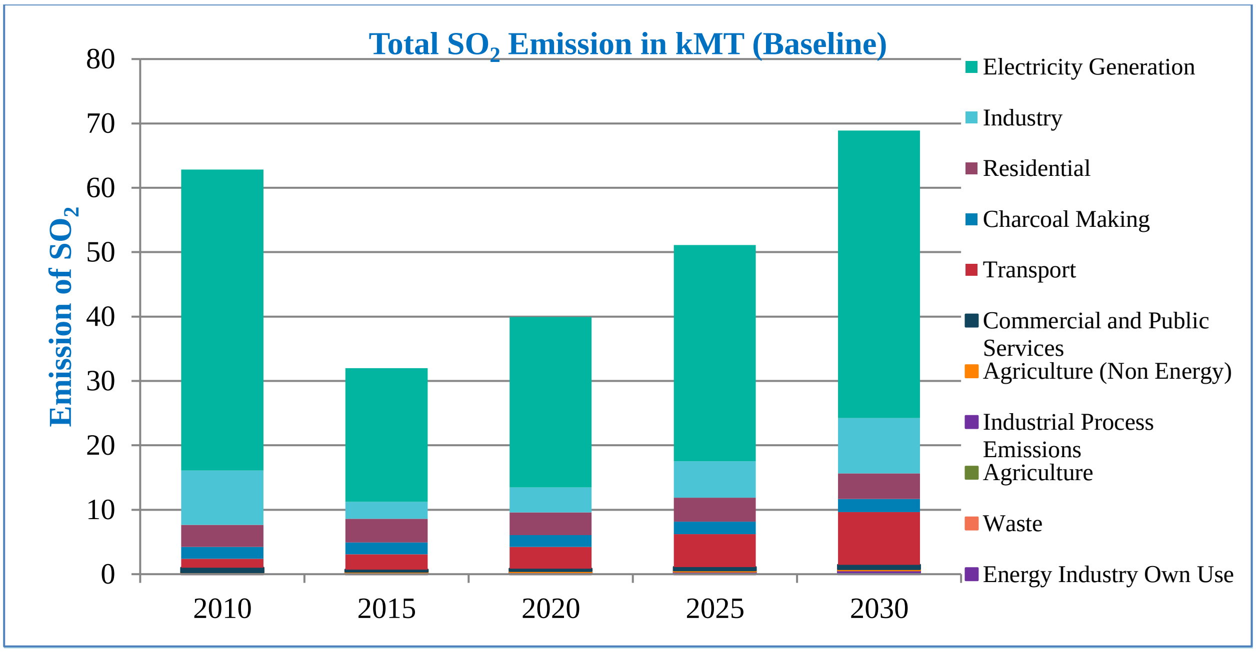

Figure 2.7 Total Sulfur Dioxide (SO_2) Emission in Cambodia between 2010 and 2030

2.3.3 Nitrogen Dioxide (NO_x)

Oxides of Nitrogen are released from vehicle emissions, burning of biomass and forests. High levels of nitrogen oxides contribute to the formation of acid rain, which in turn damages vegetation, buildings and pollute water bodies. Nitrogen oxides at high concentrations are also harmful lung irritants and can cause respiratory diseases including bronchitis and wheezing. They also react with volatile organic compounds to form tropospheric ozone, which is toxic to human health. Nitrogen oxides are also a key precursor to the formation of secondary particulate matter in the atmosphere, contributing to the levels of PM2.5 that people are exposed to and that cause negative health impacts.

In Cambodia, transport was the major source of NO_x emissions which contribute about 71.23% and electricity generation (8.03%), residential (7.81%), waste (7.25%), industry (2.87%), agriculture (1.18%) and other merge source (1.62%) were the remaining (Agriculture (Non-Energy), Charcoal Making, Commercial and Public Services, Industrial Process Emissions, Energy Industry Own Use), Figure 2.8.

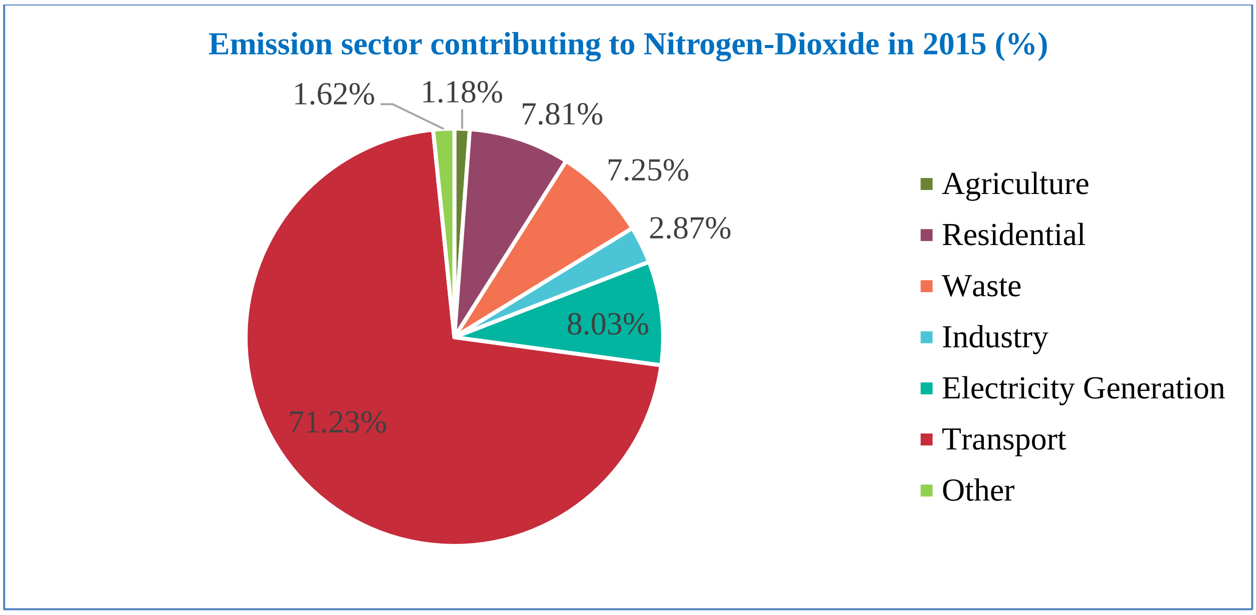

Figure 2.8 Share of Nitrogen Dioxide emission by sector in 2015

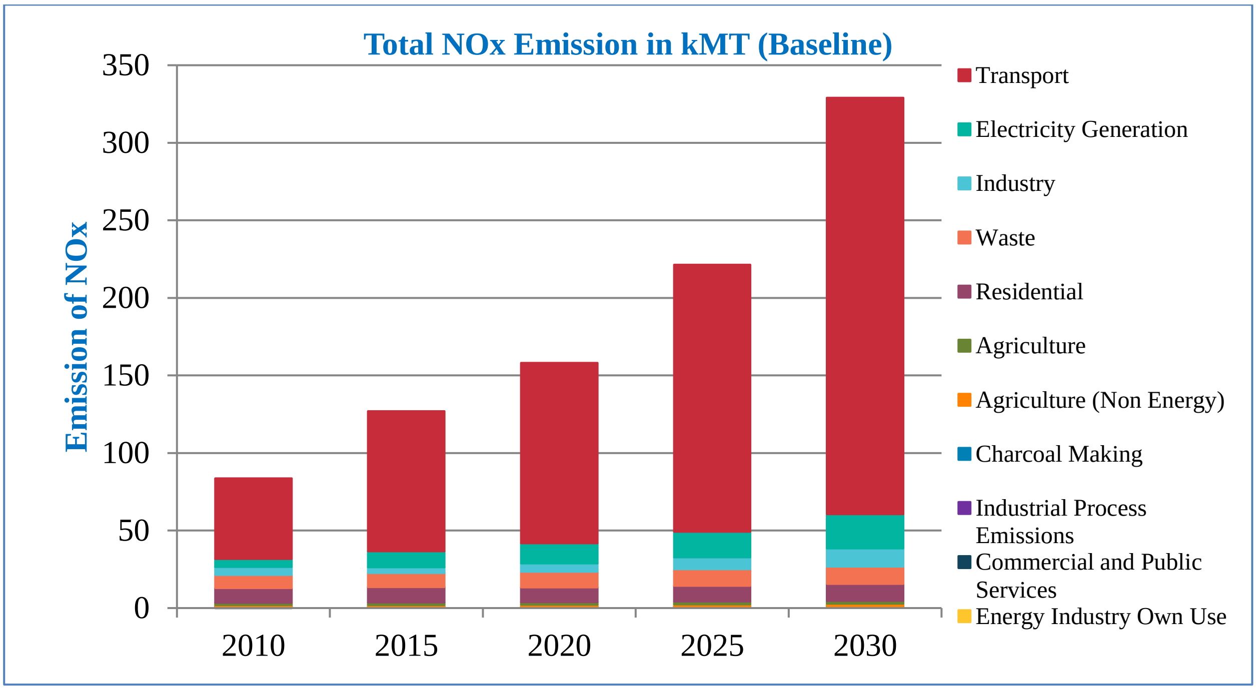

Figure 2.9 Total Nitrogen Dioxide Emission in Cambodia between 2010 and 2030

Figure 2.9 above displays the trend of NOx emissions by source sector between 2010 and 2030 under the baseline scenario, which the total NOx reaches 329 Thousand TM in 2030. The highest emissions of NO_x was observed from the transport sector, with a significant projected increase because of the emission from the freight (land) and Passenger (land) in transport sector accounted for 75.65% and 24.35%, respectively. Electricity generation is also a large source of NOx that is projected to increase in the future. Residential and industry sector are also the major source of NO_x that increase in following year.

2.3.4 Carbon Monoxide (CO)

CO is an odorless and colorless gas, the product of incomplete combustion of fossil fuels and other biomass. In Cambodia, transport sector was the main CO emissions contributor responsible for about 35.45% and residential almost 30.14%, charcoal making (25.24%), waste (579%), and the remaining 3.39% were from combined sources (agriculture, industry, electricity generation, industrial process emissions, commercial and public services and energy industry own use), Figure 2.10.

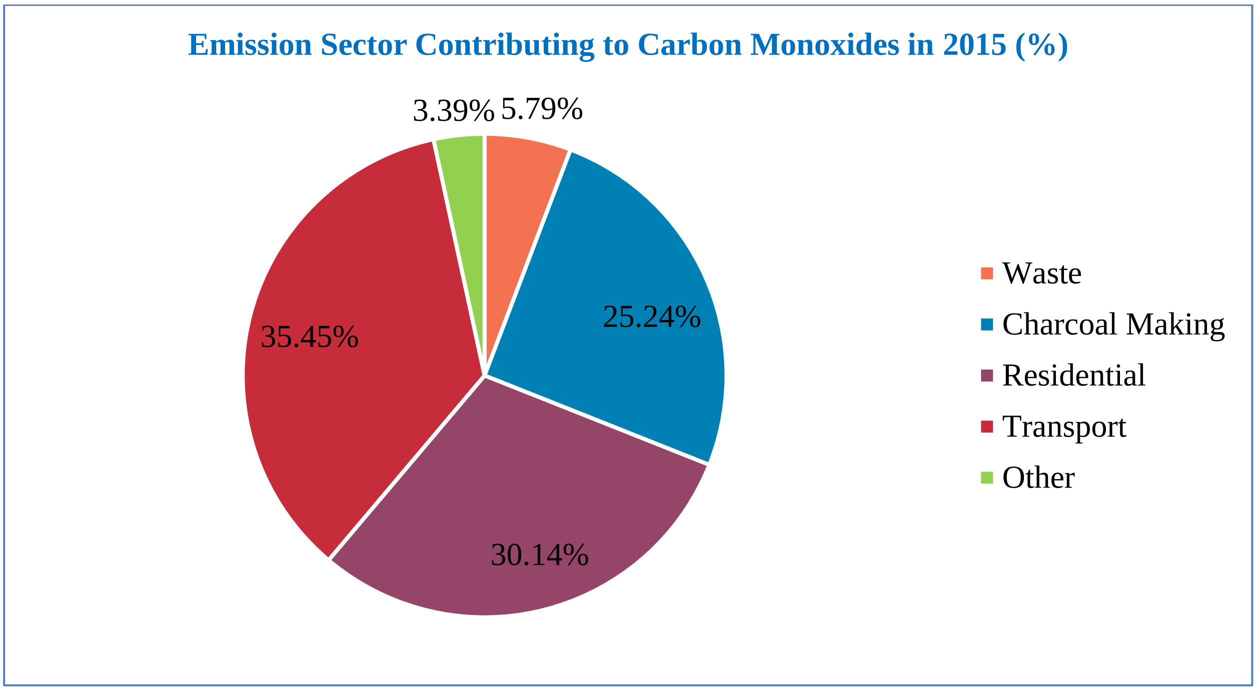

Figure 2.10 Share of Carbon Monoxide emission by sector in 2015

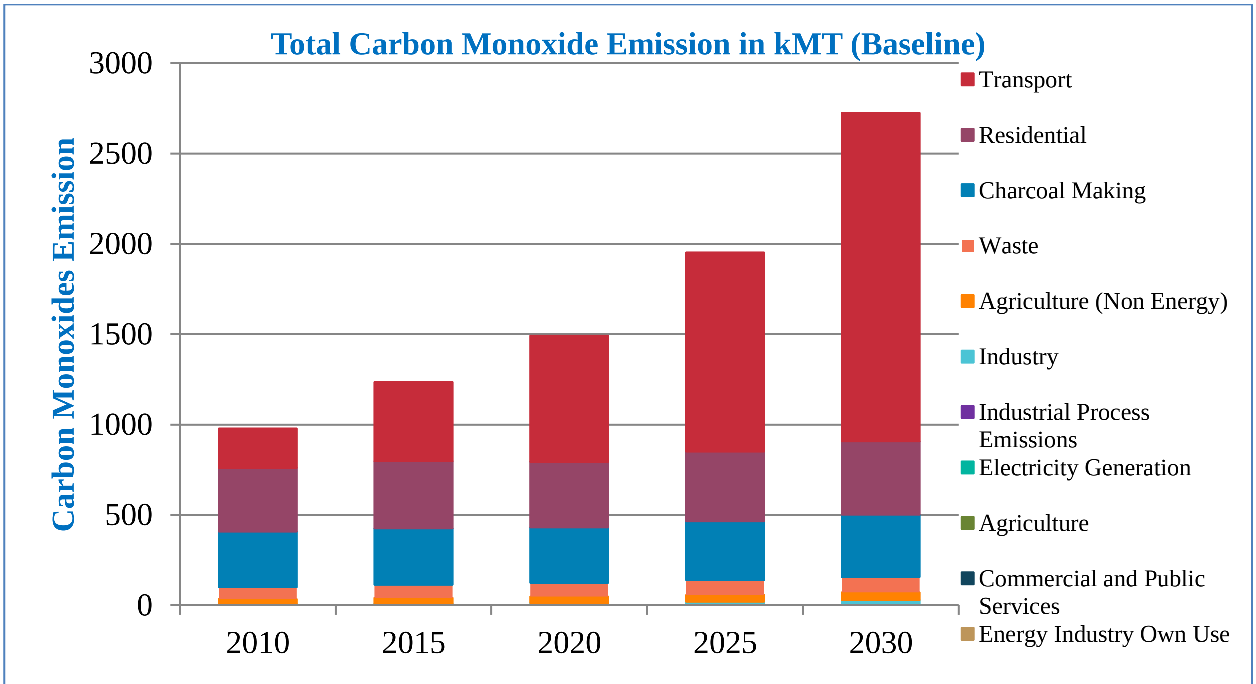

Figure 2.11 Total Carbon Monoxide Emission in Cambodia between 2010 and 2030

The total annual CO emissions from 2010-2030 are presented in Figure 2.11. It clearly shows the CO emission increased by about 3.2% annually and the CO emission elevated from 1234.18 Thousand MT to 2725.61 Thousand MT from 2010 to 2030. Transport still a leading contributor, followed by Residential and third largest was the charcoal making.

2.3.5 Ammonia (NH3)

NH_3 is commonly known occurred naturally in the environment including soil, air, and the plant also animal and the human body. Exposure to a high concentration of NH_3 can pose negative impacts on human health which influence the cardiovascular and respiratory system. NH_3 released to atmospheric environment can bind with other gaseous pollutants which are later detrimental to the natural environment.

The total emission of NH_3 in 2015 was about 124.90 Thousand MT with largely contributed by Agriculture in non-energy sector about 94.02% (117.43 Thousand MT), follow by 3.18% (almost 4.00 Thousand MT) in residential sector and 2.80% (3.50 Thousand MT) combine sector that have shown in Figure 2.12.

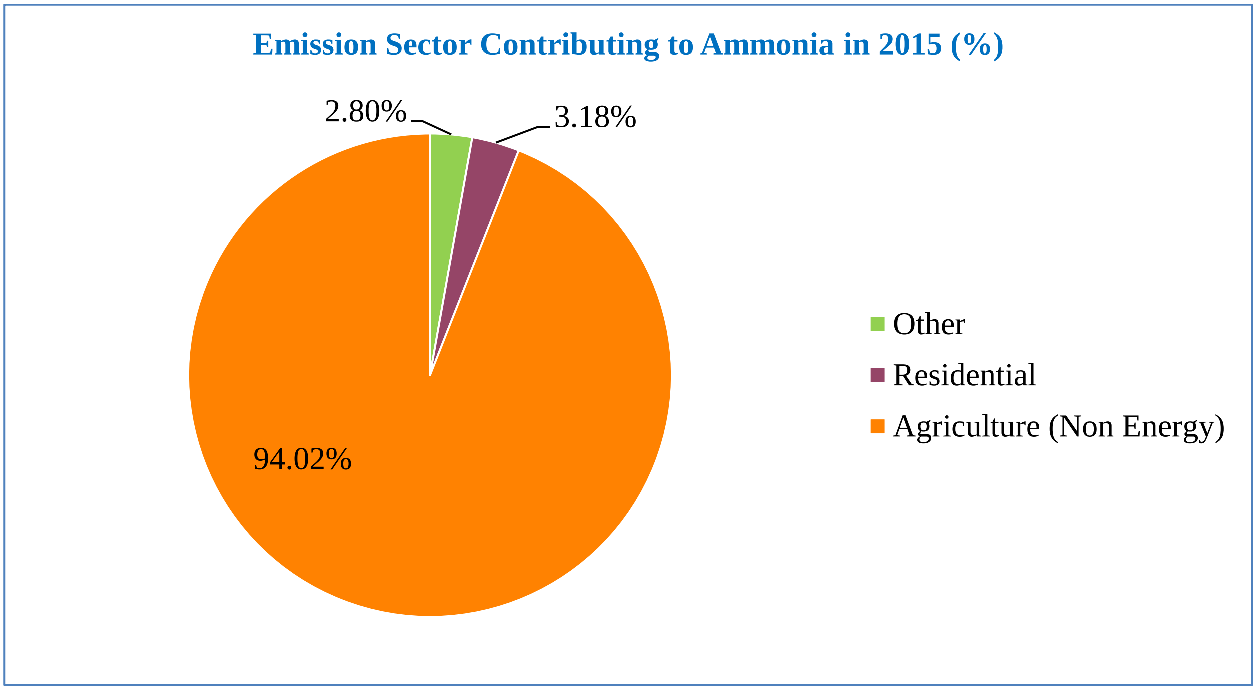

Figure 2.12 Share of Ammonia emission by sector in 2015

Figure 2.13 below is presented about the total annual emission from 2010-2030. The overall trend was downtrend as higher emission of NH_3 happened in 2015 (about 138.8 Thousand MT) as compared to the 2030 emission of about 112 Thousand MT. The major influential factor was mainly from the livestock sector where the decrease the population of livestock feeding at both household and farming.

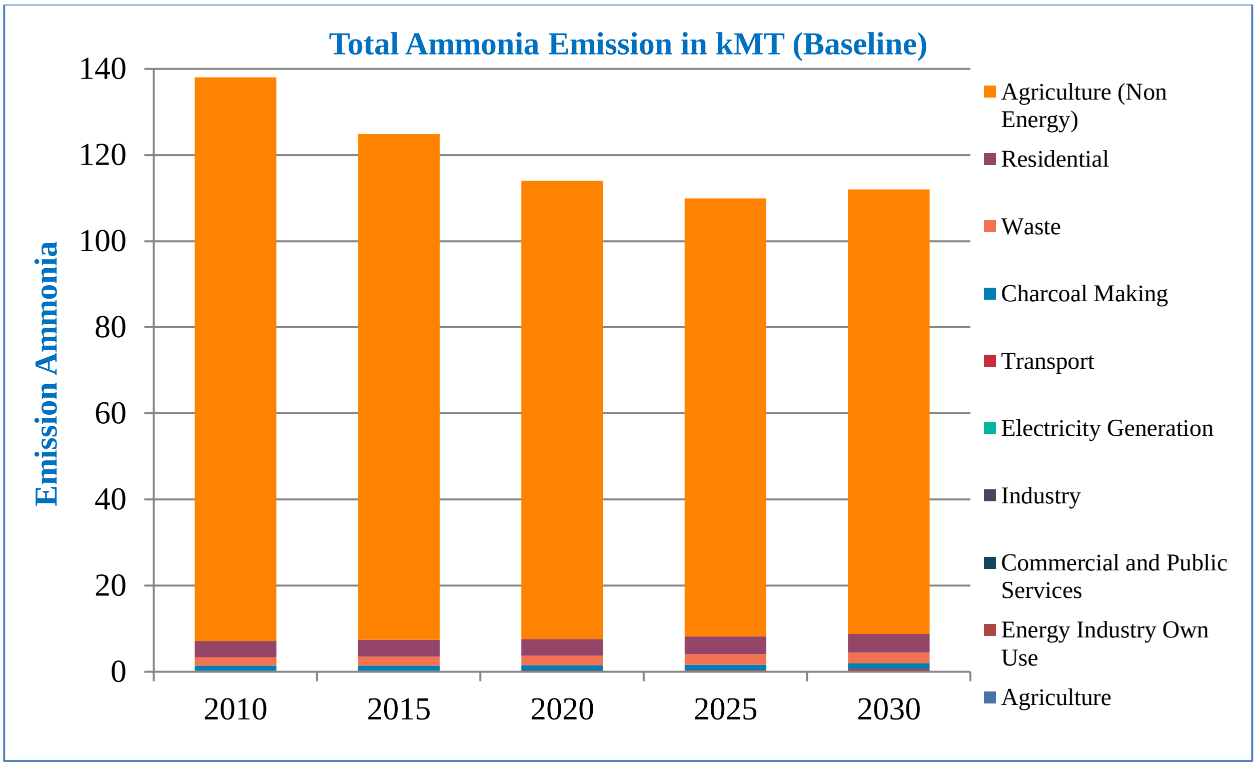

Figure 2.13 Total Ammonia Emission in Cambodia between 2010 and 2030

2.4 Short-Lived Climate Pollutants (SLCPs)

2.4.1 Black Carbon

Black carbon or soot, is a component of particulate matter (PM) and, therefore, behaves much differently than GHGs. It does not mix well in the atmosphere; therefore, its particles remain suspended in the air until they settle back on the surface, or become washed out by rain, or contribute to cloud formation. The average atmospheric lifetime of a single soot particle is only a few days. As a dark mass, black carbon particles absorb abundant amounts of energy, trapping heat and warming the climate. Like methane, for the equivalent mass emission, black carbon warms the climate more intensely than CO_2 over a short time frame, and to greater extremes. Despite lasting in the atmosphere for a few days, one ton of black carbon has a warming effect equal to 1,000 -2,000 tons of CO_2 over a 100 –year period.

Figure 2.14 shows that residential sector was the main black carbon contributor shared about 53.10% and followed by transport (25.82%), waste (16.98%), charcoal making (8.44%), industry (7.84%), agriculture in non-energy sector (3.65%) and the remaining 1.06% were from combined sources (agriculture, electricity generation, commercial and public services, and industrial process emissions).

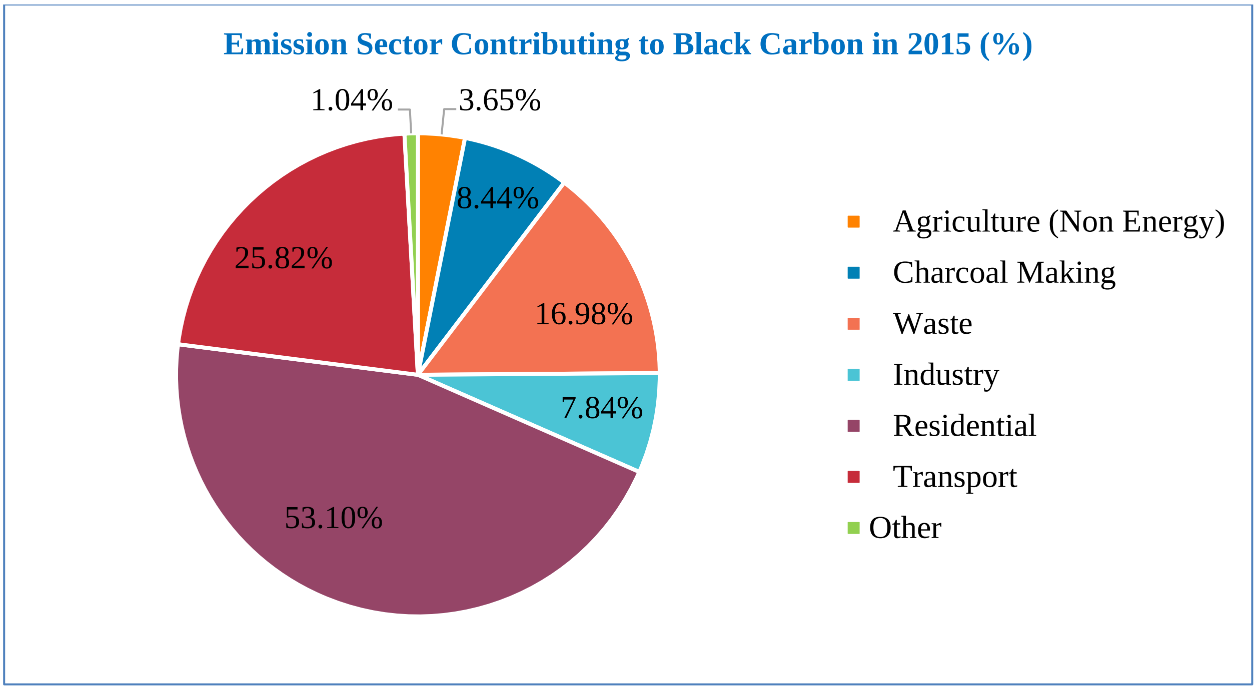

Figure 2.14 Share of Black Carbon emission by sector in 2015

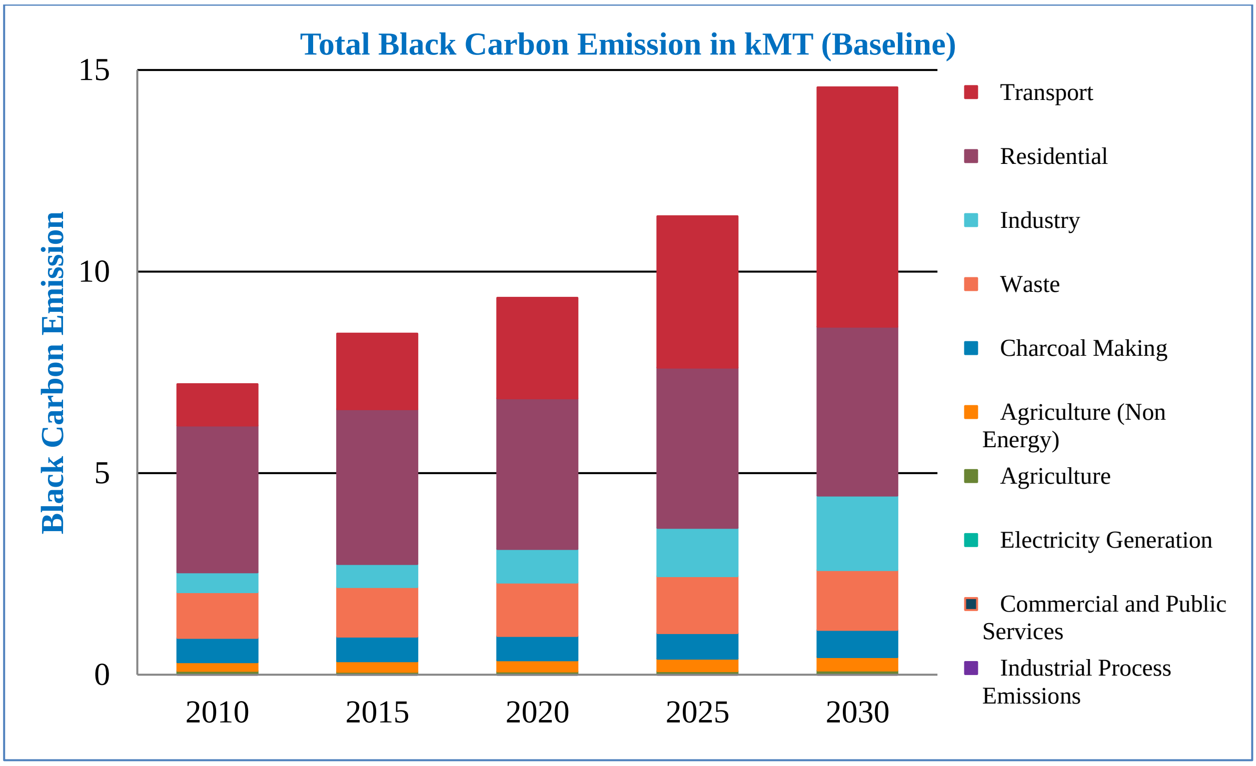

Figure 2.15 Total Black Carbon Emission in Cambodia between 2010 and 2030

Black carbon emissions are the result of incomplete combustion of biomass or fossil fuels. Major sources of black carbon include biomass cooking stoves, diesel and two-stroke engines, and open-air-burning of waste. Figure 2.15 displays the trend in emissions of black carbon by their source sectors between 2010 and 2030 under the baseline scenario. Black carbon mission increased annually with an average rate of 2.7% with the total emission reaching 14.6 Thousand TM in 2030.

The residential, waste and transport are still the major contributor to the black carbon emission over the period of 2010-2030.

2.4.2 Methane

Methane (CH4) is a colorless, odorless, and highly flammable gas composed of one carbon atom and four hydrogen atoms. It can be produced naturally and synthetically, and when burned in the presence of oxygen, it produces carbon dioxide and water vapor. The gas is also known as a significant contributor to climate change.

CH4 has an atmospheric lifetime of 12 years, but it has significant warming potential during that time. The Global Warming Potential or GWP of one ton of methane is equivalent to 21 tons of CO_2 over 100 years and equivalent to 75 tons of CO_2 over 20 years. GWPs allow comparisons of the warming impacts of different gases by measuring how much energy 1 ton of any given gas absorbs over a period of time, compared to 1 ton of carbon dioxide. Besides having a high warming impact of its own, methane also serves as a major contributor to the production of tropospheric ozone, (which is also a short-lived climate pollutant, and warms the atmosphere).

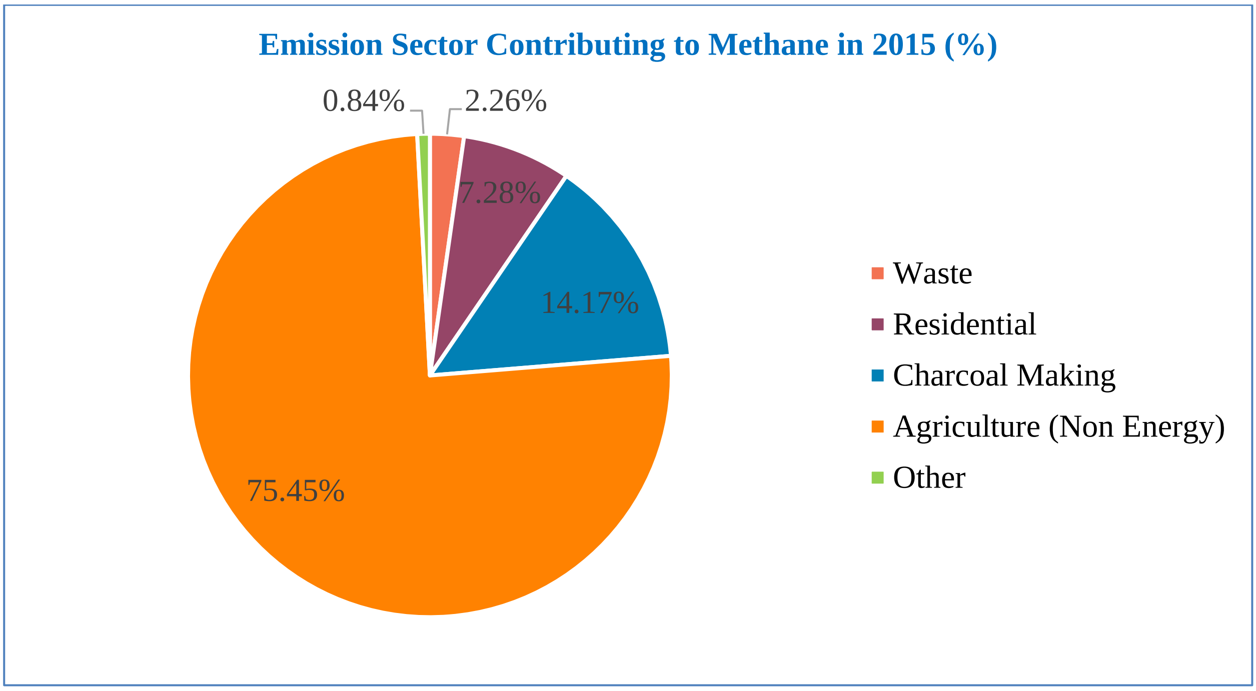

Figure 2.16 Share of Methane emission by sector in 2015

Figure 2.16 above shows the largest contributor to methane emissions is the agriculture in non-energy sector. The total annual CH4 emission in 2015 was 304.39 Thousand MT and livestock source was dominated with a share of about 75.45% follow by charcoal making is 14.17%, residential is 7.28%, waste is 2.26% and the remaining sources contributed about 0.86 collectively. For the emission from livestock, cows accounted for the largest emissions of about 80% among other species.

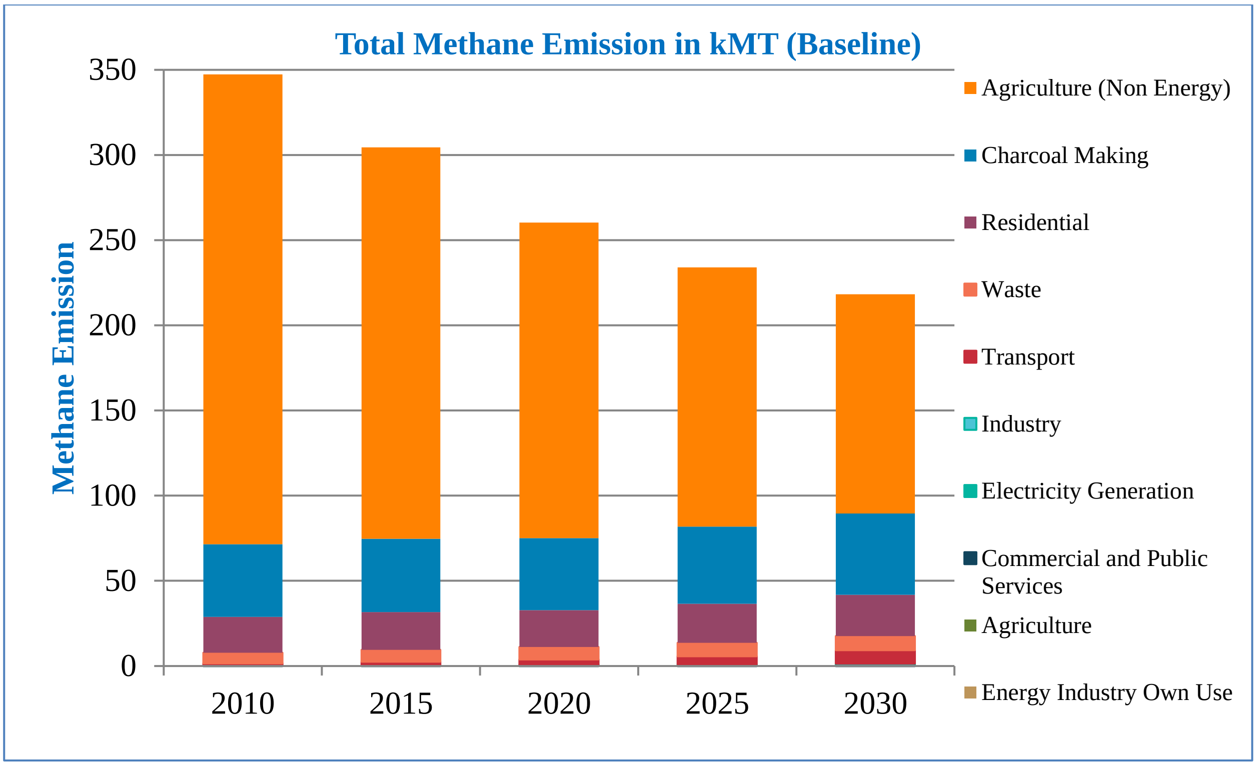

Figure 2.17 Total Methane Emission in Cambodia between 2010 and 2030

The total annual CH4 emission from 2010-2030 in agriculture (Non-Energy) shows an inconsistency pattern in emissions as downtrend as a highest emission of methane in happen in 2010 (about 347.36Thousand MT) as compare to 2030 emission about 218.2 Thousand MT (Figure 2.17), these could be explained by the decrease of domestic feeding at both households and farming. The emission of methane were remain steady from 2010-2030 in charcoal making and residential sector.

2.4.3 Non-methane volatile organic compounds (NMVOC)

Apart from affecting global warming, tropospheric ozone affects impacts evaporation rates, cloud formation, precipitation levels, and wind patterns. It also impairs the ability of plants to absorb carbon, thereby suppressing crop yields and subsequently harming ecosystems. These impacts mainly occur within the regions where tropospheric ozone precursors are emitted.

Unlike the other GHGs, tropospheric or ground level ozone (a primary component of smog) is not directly emitted. Instead, it is the product of the atmospheric reaction of a number of precursor pollutants, including methane, nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon monoxide (CO). Tropospheric ozone has an atmospheric lifetime of approximately 3 weeks. The major emission sources of ozone precursors methane and NOx were discussed in earlier sections. Figure 2.16 shows that for VOCs, which also contribute to ozone formation, the major source is the transport sector.

Non-methane volatile organic compounds (NMVOC) are toxic air pollutants that may cause cancer, brain and nervous damage, and other adverse effects on humans. Although some VOCs are naturally-occurring, many come from human sources such as paint and solvents, adhesives, petroleum products, pharmaceuticals and refrigerants. The contributing emission sources to NMVOCs is illustrated in Figure 2.18. The total annual NMVOCs in 2015 were 462.16 Thousand MT with largely contributed by transport (41.00%) and residential (25.53%). Charcoal making shared (22.84%), waste contributed (9.19%) and the remaining was 1.45% is the combine source (industry, agriculture, industry process emission, electricity generation, commercial and public services, and energy industry own use).

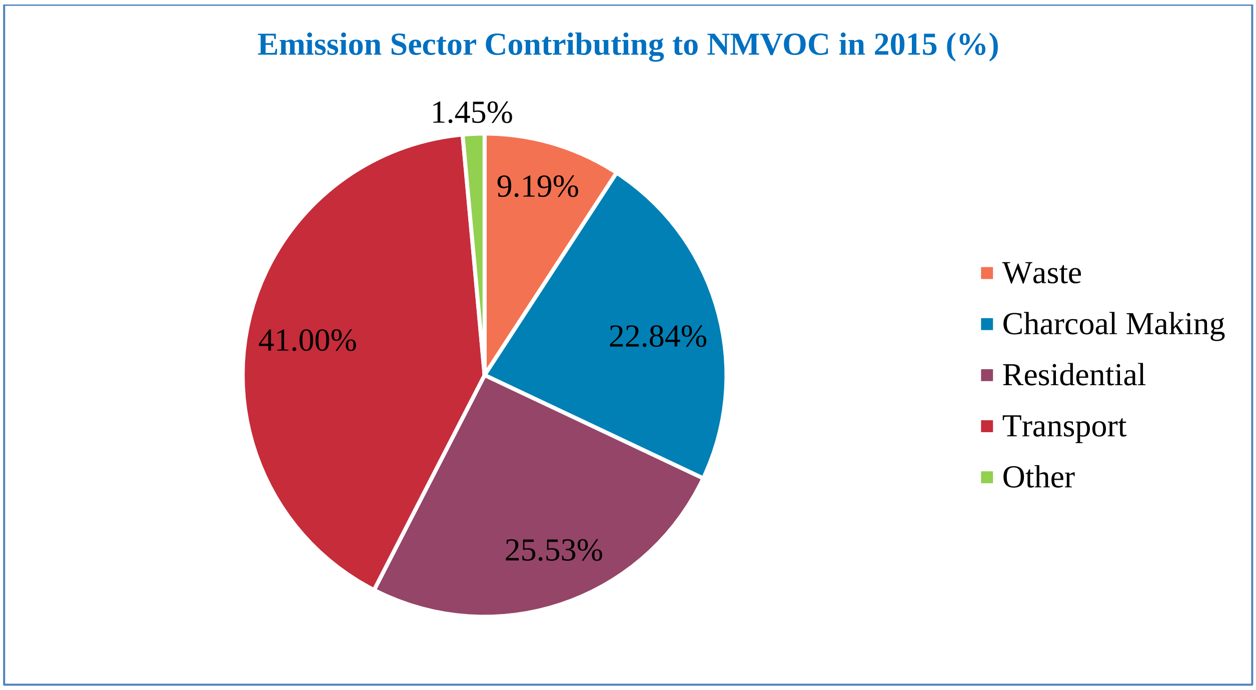

Figure 2.18 Share of NMVOCs emission by sector in 2015

Between 2010-2030, Figure 2.19, the NMVOCs leveled up from 346.37 Thousand MT to 1119.21 Thousand MT in 2030 with an estimated average growth rate of 3.45% per year. Residential and Charcoal making sources show an increasing trend that aligned with the population growth and the demand for solid fuels for daily cooking. Moreover, transport sector also increases dramatically from 85.85 Thousand MT in 2010 to 805.42 Thousand MT in 2030 with an estimate average growth rate of 41.91% per annual. It is because of the passenger car increase from 2010-2030 that is further described in transport section (Section 2.6.1).

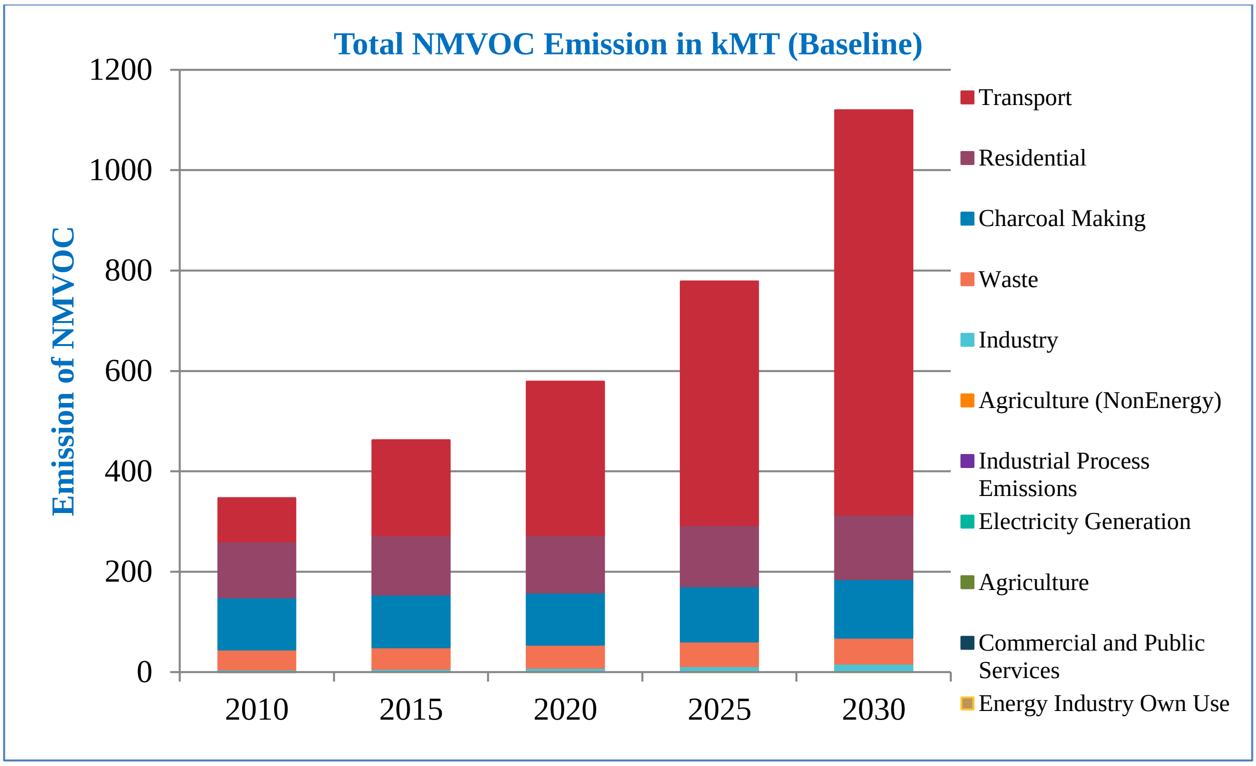

Figure 2.19 Total NMVOC Emission in Cambodia between 2010 and 2030

2.5 Green House Gases (GHGs)

GHGs, which trap heat in the atmosphere, are the principal cause of climate change. Carbon dioxide (CO_2) makes up for an estimated 76 percent of anthropogenic GHG emissions globally, followed by methane and nitrous oxide. Methane emissions in the Cambodia are described above as it is also a short-lived climate pollutant. CO_2 has a much longer lifetime than Methane, and remains in the atmosphere for around a hundred years.

In Cambodia, the analysis has shown that the major sources of greenhouse gases are also major sources of air pollutants. Transport is the major source of CO_2, and is simultaneously a major source of NOx. Electricity generation and Waste is the major source of SOx and methane, and is also a major source of many other air pollutants. Therefore, there is a large potential for developing integrated strategies to simultaneously improve air quality and reduce the Cambodia's very small contribution to global warming. Like air pollutants and SLCPs, emissions of GHGs are also projected to grow substantially in the future due to increase in population, and demand for energy.

2.5.1 Carbon Dioxide (CO_2)

Carbon Dioxide (CO_2) emission in Cambodia emanated from transport, electricity generation, industry process emission, industry, commercial and public services, agriculture, and other combined sources.

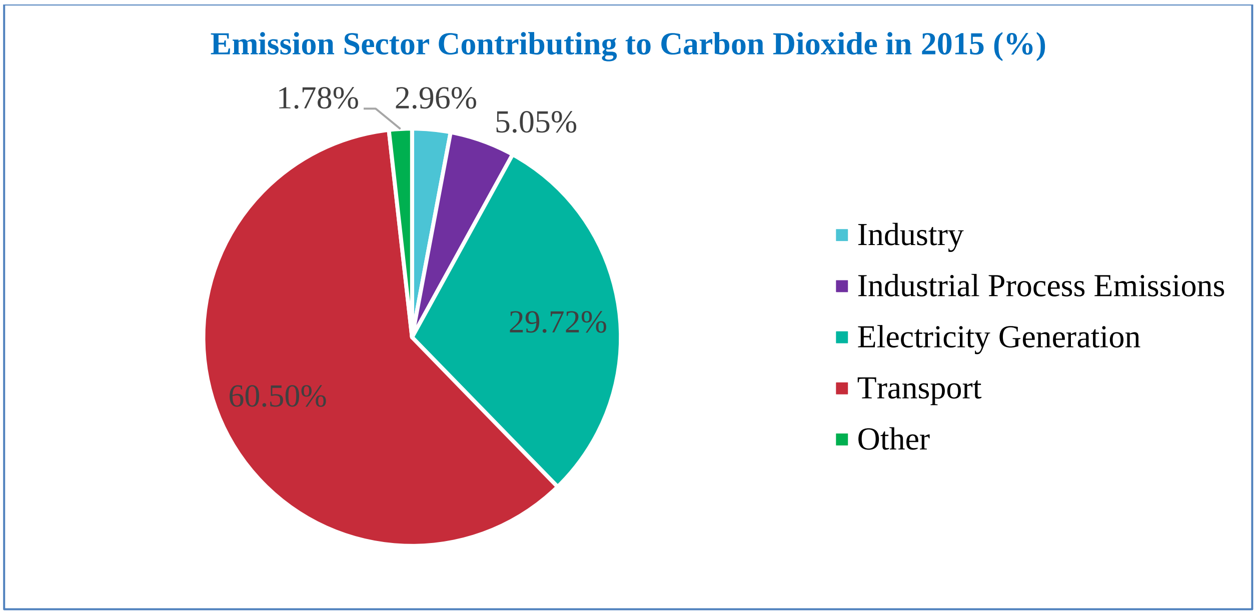

Figure 2.20 Share of Carbon Dioxide emission by sector in 2015

Figure 2.20 shows that the largest CO_2 emission come from the transport of 60.50%. The second largest emission of CO_2 was electricity generation of 29.72%, followed by industrial process emission and industry was 5.05% and 2.96%. For the emission from 2010-2030 in figure 2.21 below shows that increasing bar from 9161.76 Thousand MT to 40150,86 Thousand MT with annual increase rate 3.86%.

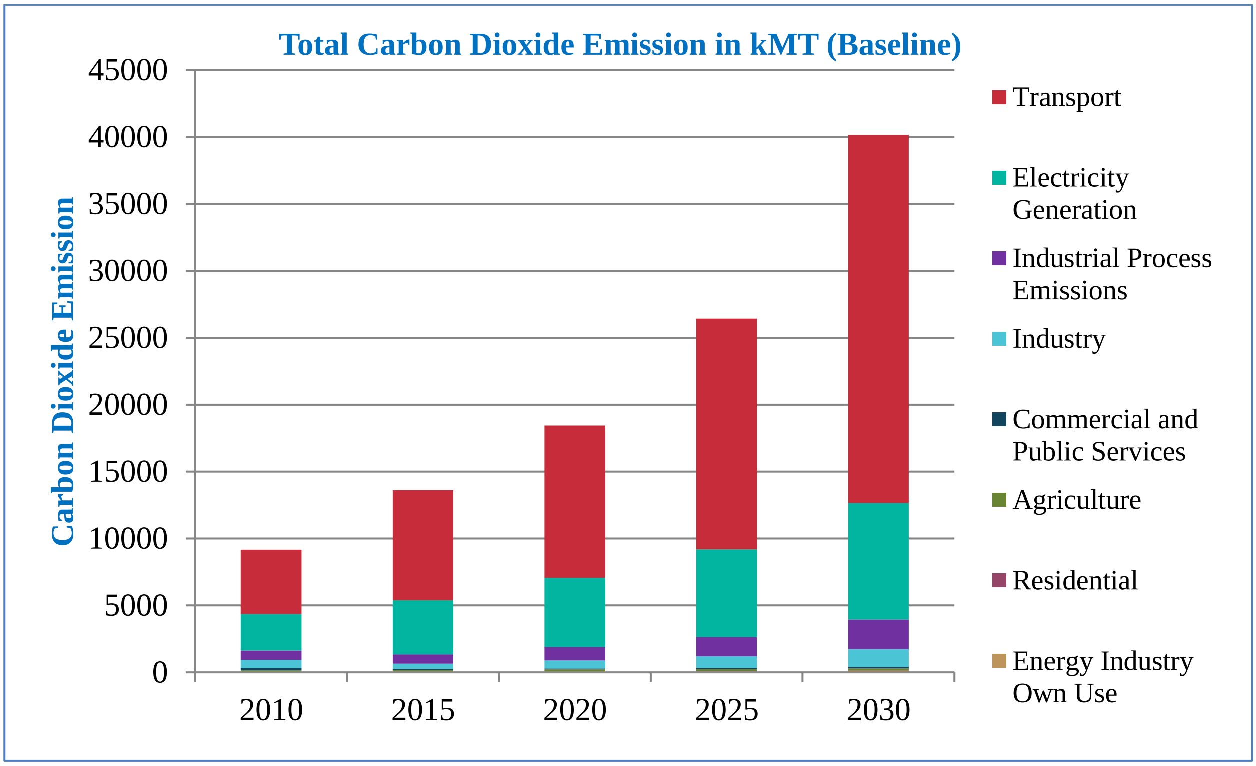

Figure 2.21 Total Carbon Dioxide Emission in Cambodia between 2010 and 2030

2.6 Emission Source Sectors

Having described the main pollutants considered in this plan in Sections 2.2-2.4 above, the major source sectors identified, specifically transport, electricity generation, industry, residential, charcoal making and other contribute sector, are now considered in more detail in turn in the sub-sections below.

2.6.1 Transportation

Transport is one of the major sources of atmospheric pollutions. The transport sector covers on-road transport, waterway, railway, and aviation. However, railway and aviation were not considered in this estimation due to lacking reliable data. Thus, only on-road transport and waterways were considered. Following the growth in population and urbanization, there has been a rapid increase in the number of vehicles imported into Cambodia. According to the annual report of Ministry of Public Works and Transport, the total registered vehicles have increased more than 52.70% from 2010 to 2015. The total number of vehicles registered had increased from 342,076 in 2015 to 540,621 in 2019 by approximately 65% (MoPWnT, 2019).

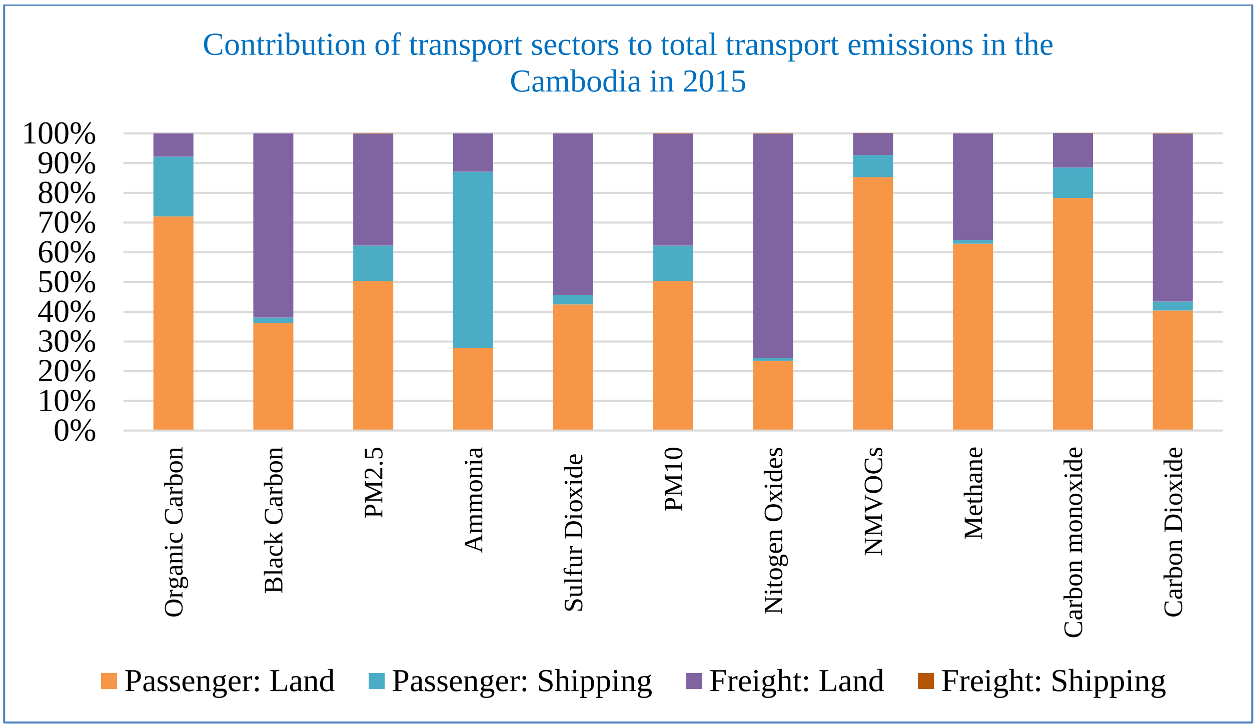

Figure 2.22 Contribution of transport sectors to total transport emissions in the Cambodia in 2010

The figure 2.22 shows how the different transport sectors contribute to emissions of different pollutants in the base year 2010. For instance, the highest share of direct PM2.5 emissions were contributed from the road transport of freight (40%), followed by passenger of road transport emissions (38%). Note that shipping also contribute about 21% share of PM2.5 by transport goods or passengers. The reason of this significant increase was the increasing of the huge number of vehicles in Cambodia with the annual increase rate of 17.54% in the last 5 years.

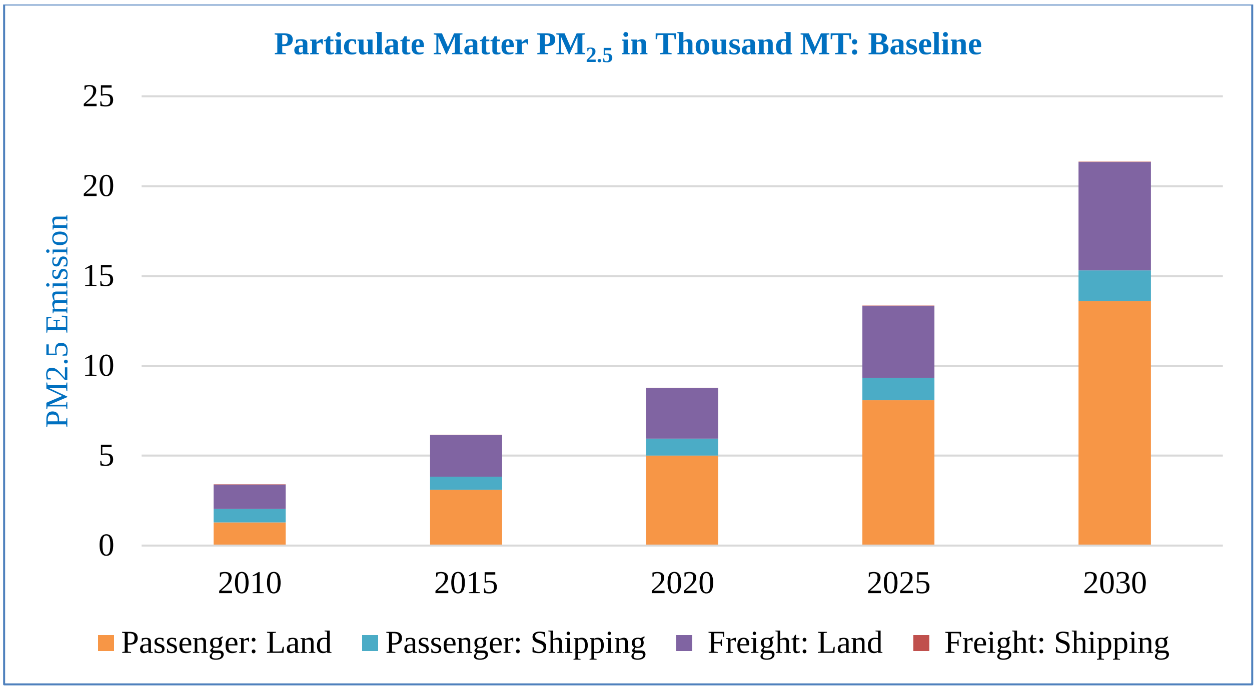

Figure 2.23 Progression of PM2.5 emissions from the transport sector between 2010 and 2030

2.6.2 Electricity Generation

Two important variables (inputs) to estimate the emissions from the electricity generation are process share and process efficiency. The National Energy Statistics for Cambodia offered the historical data from 2010-2015 that could serve the purpose of having the process share (%), Table 2.4 estimated using the electricity production from a sum of different fuel types. The economic development and population growth affect electricity consumption. The electricity generation increased almost 5 times between 2010 and 2015 and above 2 times higher in 2015 as compared to 2014 (of 2,981 GWh). The electricity generation (GWh) was converted to ktons of electricity generation by each fuel type.

Table 2.4 Electricity Generation by Fuel Types (GWh)

Fuel Types	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Biomass	7			6	11	27
Coal	32	47	37	169	863	2,128
Diesel Oil	12	11	8			
Heavy Fuel Oil	773	783	746	477	266	141
Hydro	31	47	517	1,009	1,841	2,153
Imported	1,389	1,662	1,990	2,028	1,531	1,249
Thermal wood	6	14	12			
Total	**2250**	**2564**	**3310**	**3689**	**4512**	**5698**

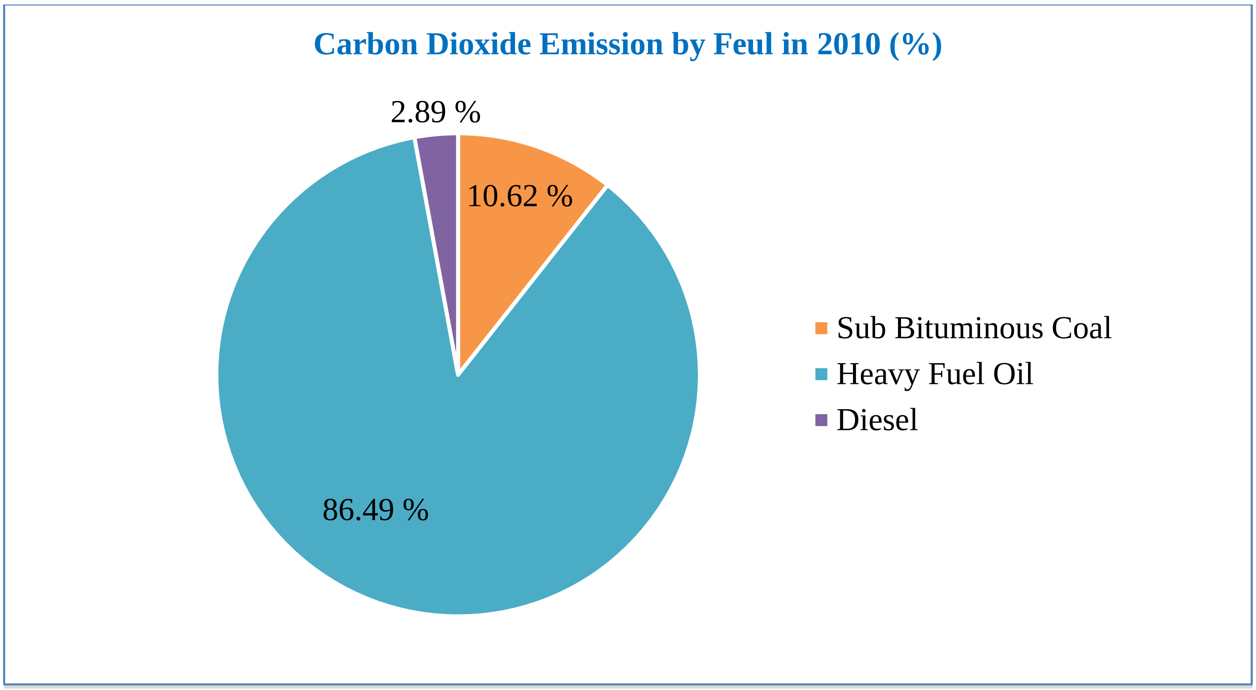

Figure 2.24 Share of Carbon Dioxide emission by Fuel type in 2010, (%)

Figure 2.24 above shows the carbon dioxide emission by percent of fuel type in 2010. The largest share of carbon dioxide emission about 86.49% by heavy fuel oil. The second largest of carbon dioxide emission share about 10.62% by sub bituminous coal and follow by diesel is about 2.89% in 2010.

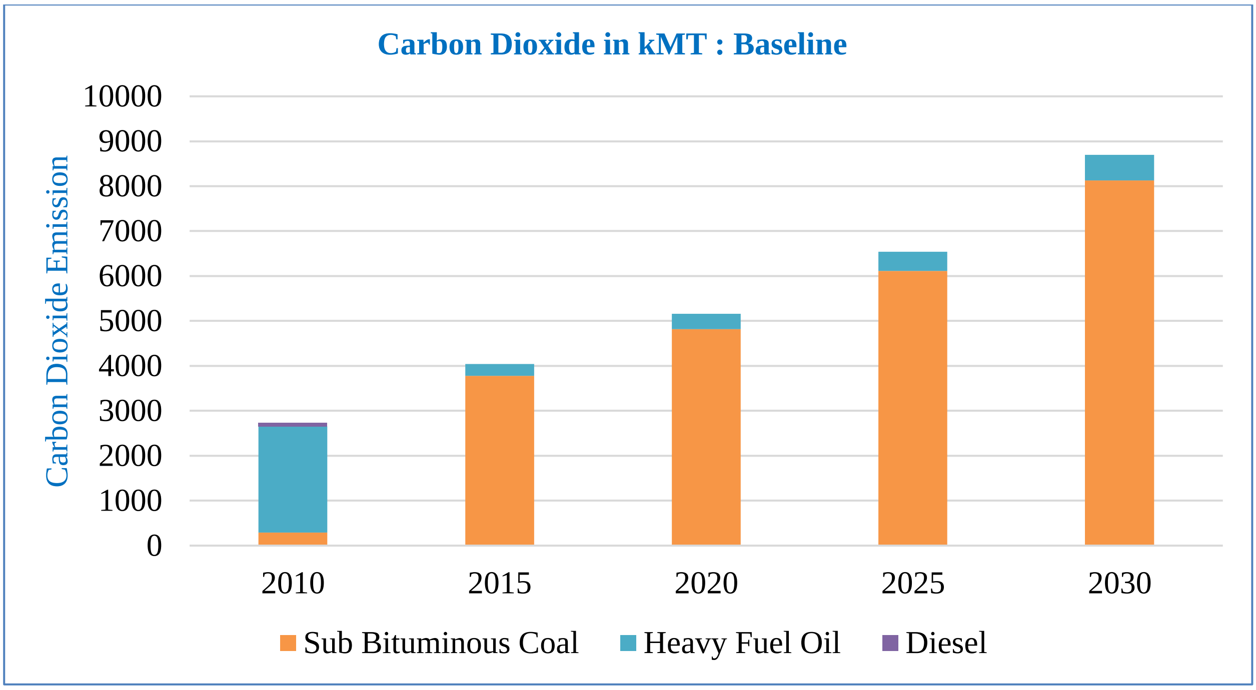

Figure 2.25 Progression of Carbon dioxide emissions from electricity generation between 2010-2030

Figure 2.25 above focuses on carbon dioxide emissions and the emission trend for the fuel type in electricity generation between 2010 and 2030 under baseline scenario. Due to expected increases in economic growth and population, emission of carbon dioxide from heavy fuel oil was huge decrease in 2010 compared to 2015, because heavy fuel oil was replaced by sub bituminous coal in 2015 and the trend of carbon dioxide emission from sub bituminous coal are increase substantially into the future.

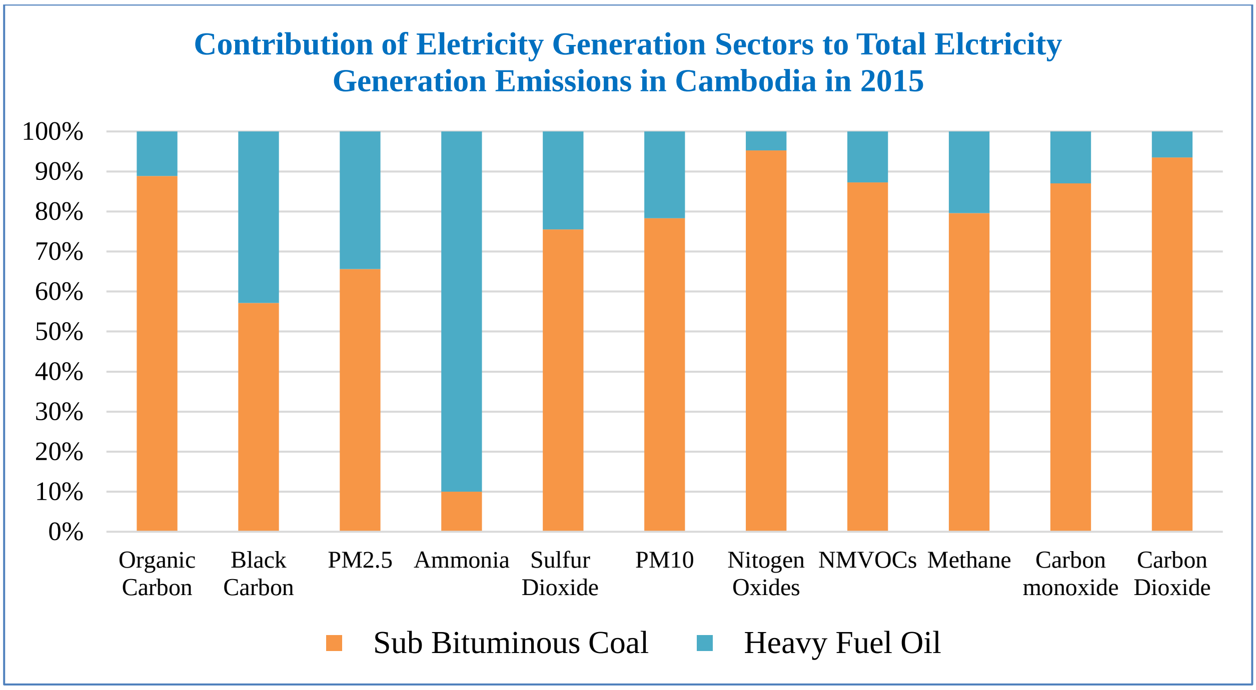

Figure 2.26 Contribution of Electricity generation sectors to total electricity generation emissions in the Cambodia in 2015

The figure 2.26 shows how the different electricity generation sectors contribute to emissions of different pollutants in the base year 2015. For example, the highest share of ammonia was contributed from the heavy fuel oil (90%) and from other pollution were contributed by sub bituminous coal about (70%-80%)

2.6.3 Industry

Several fuel types (coal, petroleum products, biomass, and electricity) were reported in the MME & ERIA (2016) and is used for the industrial sector (such as Food, beverages, and tobacco, Paper, pulp, and printing, Construction, Textile and Leather, Garment and other industry); however, the detailed process disaggregation was not available. The coal consumption is an increasing trend over time in which 13 ktons in 2015 as compared to 5 ktons in 2010 due to the investment on the thermal coal power plant in Cambodia and expecting in a growing trend in the future. In the same period, petroleum products are in declining trend i.e., a total of 192 ktons in 2010 dropped to 112 ktons in 2015. Both biomass and electricity consumption are steadily increasing over the same period. The total energy consumption in the industry sector is summarized in Table 2.5.

Table 2.5 Total Energy Consumption in Industry Sector (ktons)

Types of Fuel	2010	2011	2012	2013	2014	2015
Coal	5	6	6	7	9	13
Petroleum Products	192	204	197	177	154	112
Gas / Diesel Oil (DO)	66	69	77	74	82	77
Fuel Oil (FO)	124	129	116	98	66	27
LPG	0	0	0	1	1	2
Other petroleum products (OPP)	3	6	4	4	5	6
Biomass	244	254	265	276	289	312
Electricity	42	54	77	71	91	98

Figure 2.27 shows that the largest carbon dioxide emitter was from the Industrial Process Emissions (51.92%), followed by about 48.08% from industry sector in 2010. For figure 2.28 shows about the overall trend of carbon dioxide emission from 2010 to 2030. It was downtrend as higher emission in industry sector happened in 2010 (about 1322.43 Thousand MT) as compared to the 2015 emission of about 1089.13 Thousand MT. The major changes was mainly from the heavy fuel oil were replaced by sub bituminous coal similar case to the electricity generation as well.

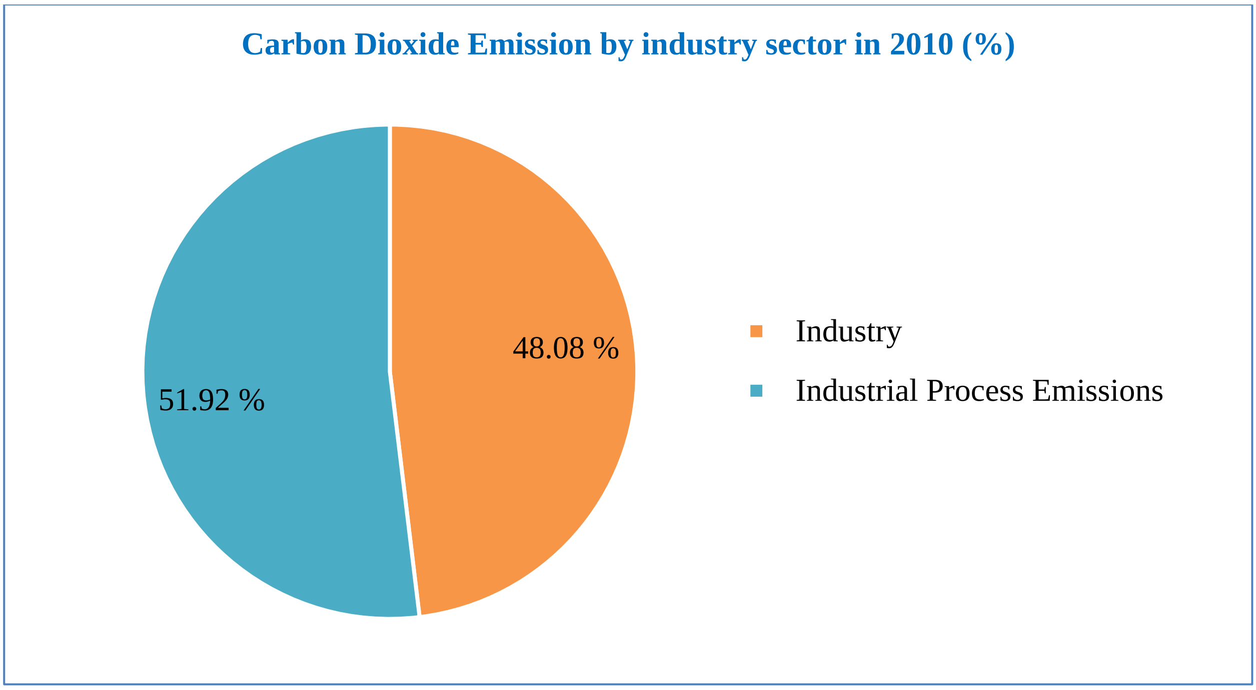

Figure 2. 27 Share of Carbon Dioxide emission by industry sector in 2010, (%)

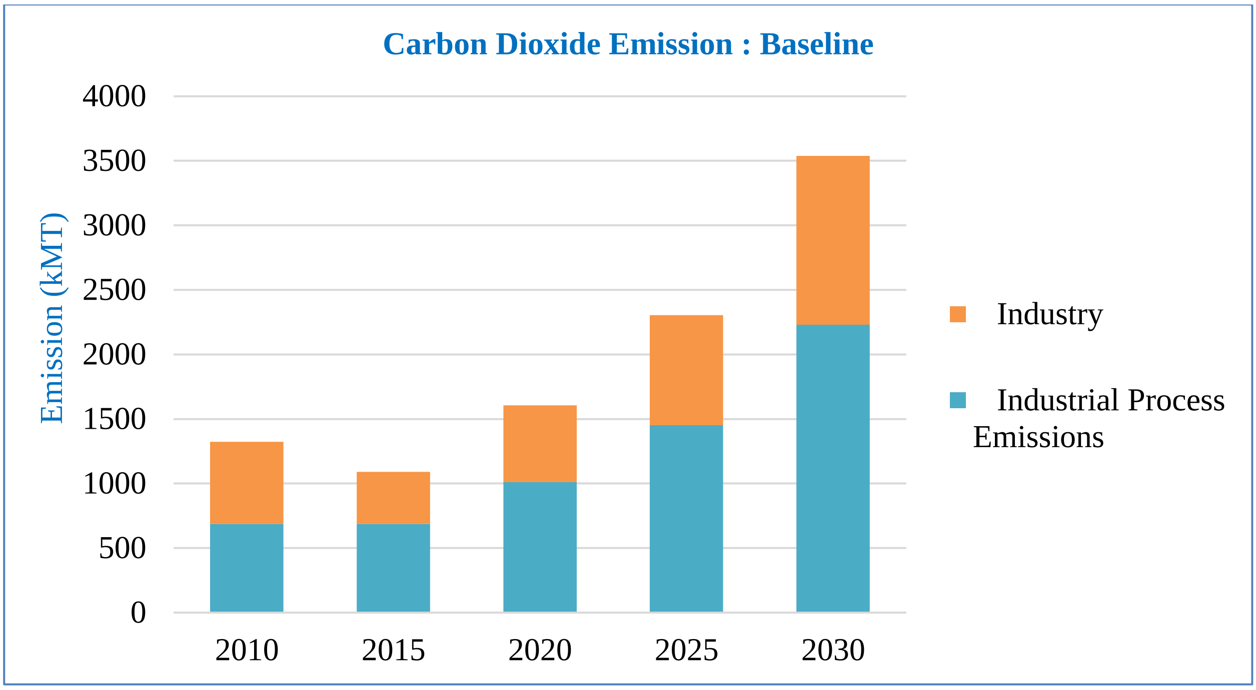

Figure 2.28 Progression of Carbon dioxide emissions from industry sector between 2010-2030

The figure 2.29 shows how the different industry sectors contribute to emissions of different pollutants in the base year 2015. For instance, the highest share of all pollution emissions was contributed from the industry (80%-90%) except the carbon dioxide the highest share is from industrial Process Emissions about 63%.

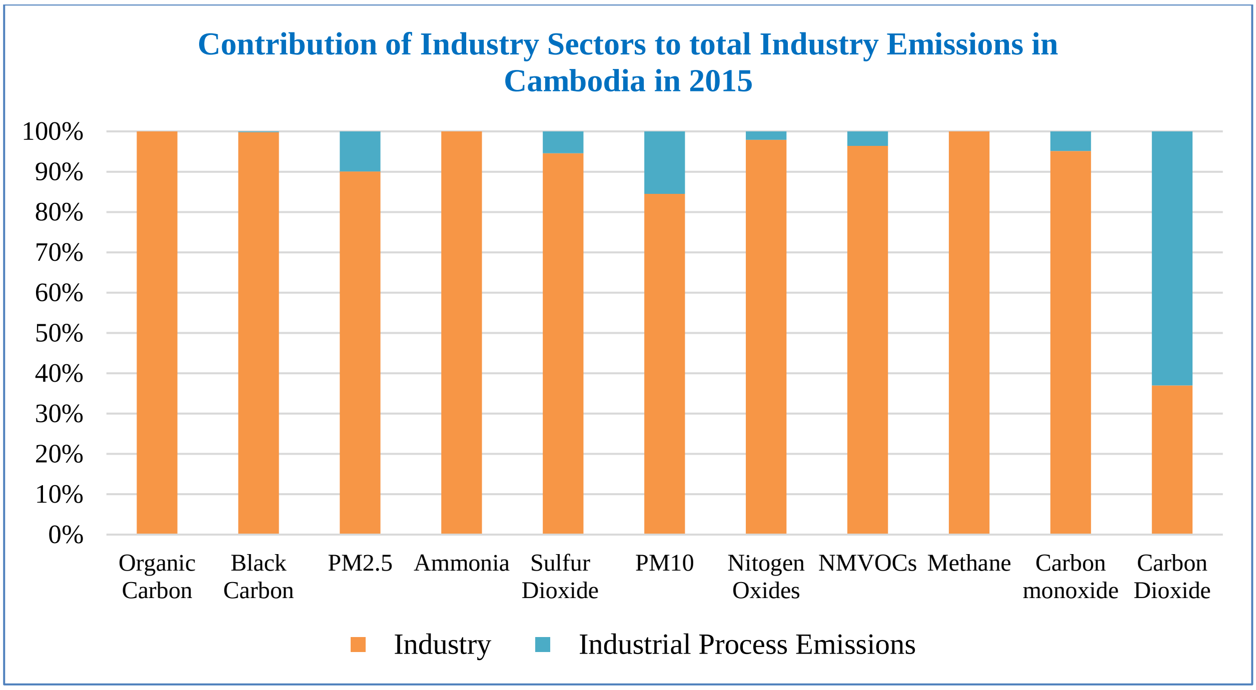

Figure 2.29 Contribution of industry sectors to total industry emissions in Cambodia in 2015

2.6.4 Residential

Key activity data for energy consumption in the residential sector (in ktons) for lighting and cooking purposes is presented in Table 2.6. These data were derived from the Cambodia

National Energy Statistics 2016 for the period 2010-2015 (MME & CERIA, 2016). The data from ERIA for the period of 2010 to 2015 was used to estimate emission from residential and commercial sectors. Energy for cooking and lighting was split based on fuel types. The consumption of the electricity as the lighting source at households was increased gradually from 75 ktons in 2010 to 131 ktons in 2015 while the no more kerosene being used since 2014. For cooking, solid fuels (firewood and charcoal) remained shared the largest fuel mixed in Cambodia and followed by LPG. Biogas statistics from 2010-2015 reported by the National Biodigester Programme were included.

Table 2.6 Energy Consumption for Residential Sector (ktons)

Description	2010	2011	2012	2013	2014	2015
Lighting						
Kerosene	9	6.5	2	2	0	0
Electricity	75	73	93	102	114	131
Cooking						
Firewood	636.91	665.31	694.03	724.07	758.46	770.23
Charcoal	120.23	125.59	131.01	136.68	143.17	145.39
Biogas	0.86	1.11	0.97	0.26	0.38	0.38
LPG	7	8	3	3	4	5

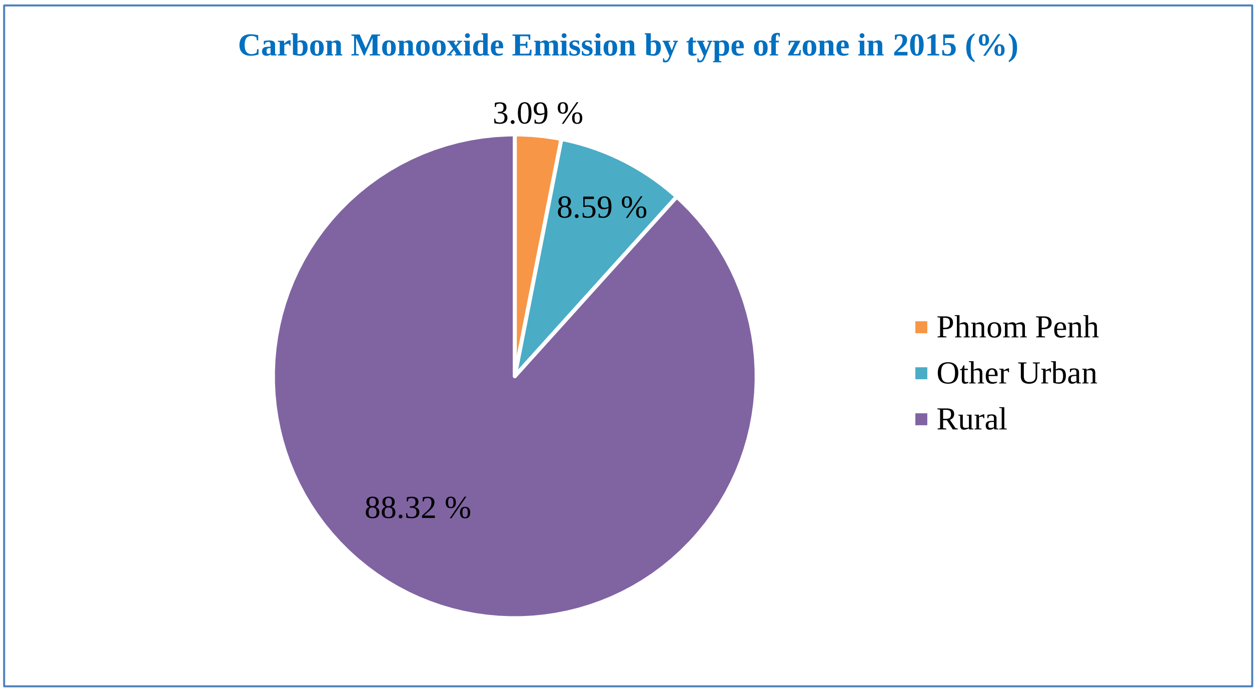

Figure 2.30 Share of Carbon Monoxide emission by type of zone in 2015, (%)

The total emission of carbon monoxide by residential sector in 2015 was about 371.97 Thousand MT, the main emitter were from rural area about 88.32%, other urban area was about 8.59%, and Phnom Penh city was about 3.09%, Figure 2.30.

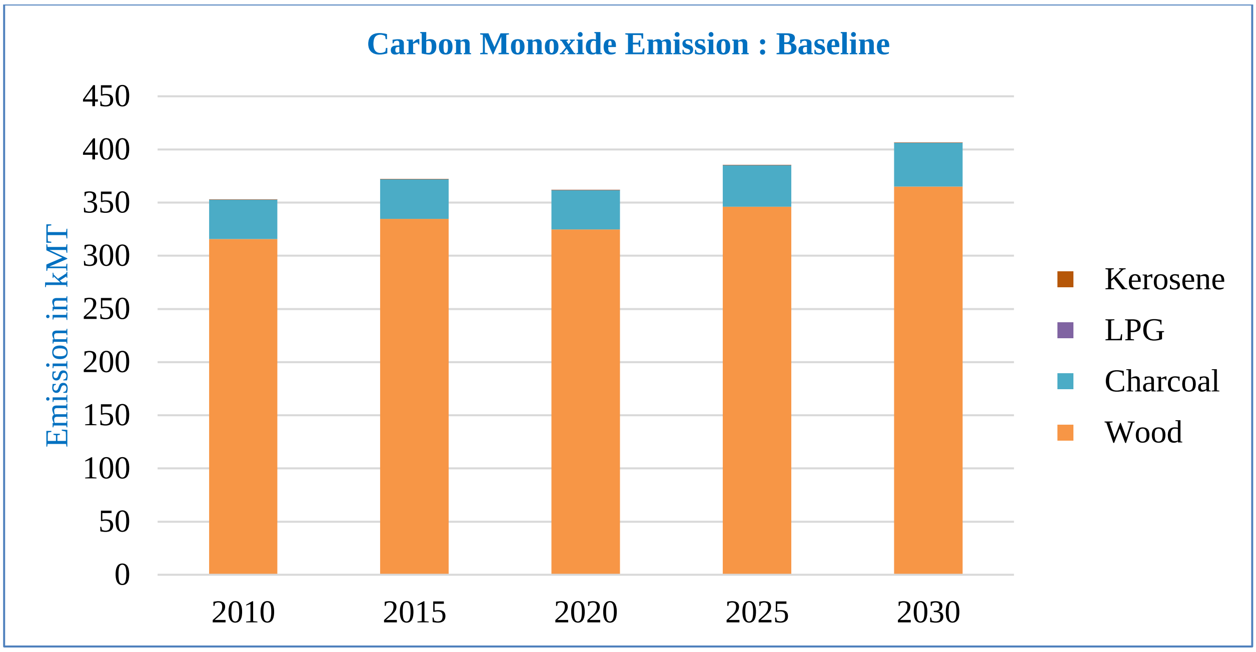

Figure 2.31 Progression of carbon monoxide emissions from the residential between 2010-2030

The total annual carbon monoxide emissions from 2010-2030 in residential sector are presented in figure 2.31. It clearly shows the carbon monoxides emission in residential sector mainly increase from 2010-2030 by wood in rural area. The second contribute of carbon monoxides in residential sector from 2010-2030 by charcoal and the remaining of carbon monoxides from residential was LPG and Kerosene. According to the graph its shows that from 2010-2020 the emissions is almost stay still; however, carbon monoxide starts to increase slightly from 2020-2030.

The figure 2.32 shows how the different residential sectors contribute to emissions of different pollutants in the base year 2015. For instance, the highest share of carbon dioxide was contributing in Phnom Penh area (48.76%), follow by rural area (32%) and other urban area. For other pollution such as organic carbon, black carbon, PM2.5, PM_{10}, ammonia, Sulfur Dioxide, Nitrogen Oxides, NMVOCs, and Methane, the highest share was contributing by rural area about 80% to 90% and the rest were Phnom Penh area and other urban area.

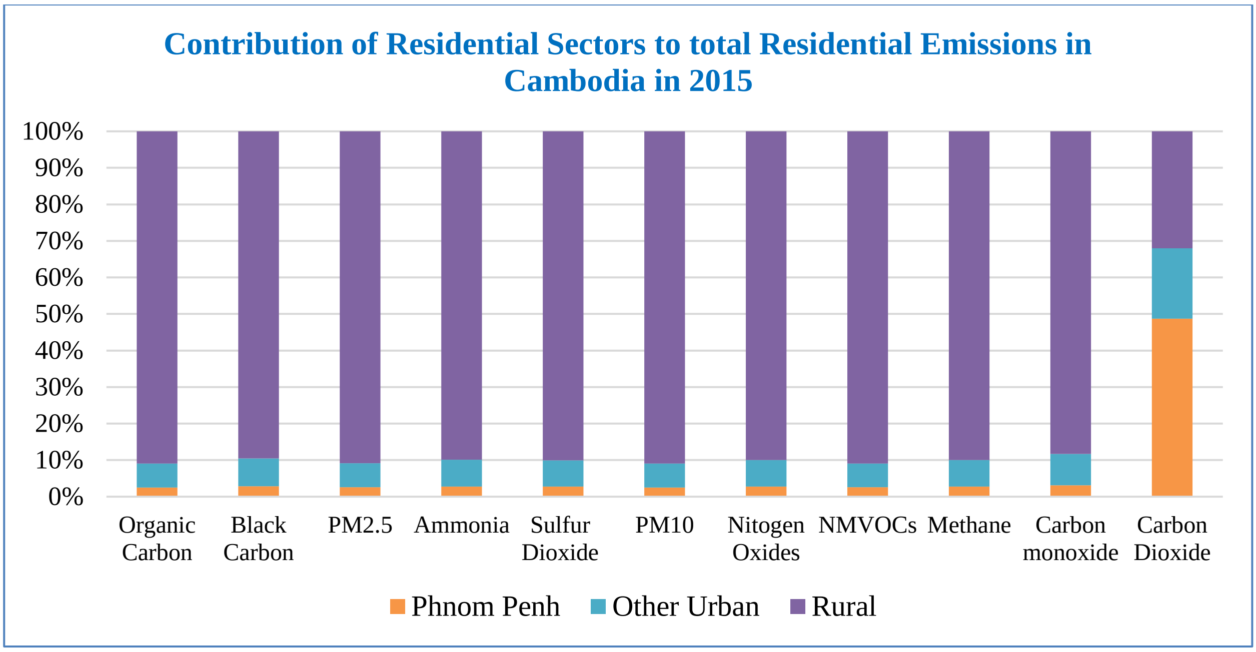

Figure 2.32 Contribution of residential sectors to total residential emissions in Cambodia in 2015

2.6.5 Other Contributing Sector

Table 2.7 shows the total amount of wood consumed for charcoal production and charcoal produced for the period of 2010 to 2015. The data derived from ERIA was used to calculate emissions from this sector. In Cambodia, charcoal making was assumed still processed in traditional kilns and only firewood was used for transformation. Of each year estimation, the process efficiency of this method is only 11.43%.

Table 2.7 Total Firewood Supplied for Charcoal Making and Charcoal Produced (ktons)

Description	2010	2011	2012	2013	2014	2015
Wood consumed	245.44	256.22	266.7	278.07	291.06	295.43
Charcoal production	28.05	29.3	30.5	31.8	33.3	33.76

Table 2.8 Charcoal Making emission by pollutants types between 2010-2030

No	Pollutants	Year				
		2010	2015	2020	2025	2030
1	Black Carbon	0.60	0.61	0.60	0.64	0.68
2	Ammonia	1.18	1.19	1.17	1.25	1.32
3	Sulfur-Dioxide	1.83	1.85	1.82	1.94	2.05
4	Organic Carbon	4.10	4.15	4.09	4.35	4.59
5	PM2.5	8.26	8.37	8.23	8.77	9.25
6	PM10	8.26	8.37	8.23	8.77	9.25
7	Methane	42.58	43.12	42.43	45.19	47.66
8	Non-Methane Volatile Organic Compounds	104.22	105.54	103.86	110.61	116.67
9	Carbon Monoxide	307.59	311.48	306.51	326.44	344.32

The total annual emission from 2010-2030 of charcoal making (Table 2.8) shows the largest pollution was carbon monoxides. Without any mitigation in carbon monoxides, there is a constant from 2010-2020 and it starts increase in carbon monoxides emission estimated from 2020-2030.

a) Agriculture (Use Energy)

As reported in the Cambodia National Energy Statistics (MME & ERIA, 2016), the most dominant fuel used for the agricultural purpose is diesel oil (DO). Cambodia is an agricultural country, the utilization of mechanical machinery for agricultural purposes is important. From the statistics, 2010-2015 indicated the increasing trend from 2010-2014 and slightly declined in 2015 (38 ktoe as compared to 2014 (50 ktoe).

Table 2.9 Energy Consumption for Agriculture

Type of fuel	2010	2011	2012	2013	2014	2015
Agriculture						
Gas/Diesel oil	32	38	44	42	50	38

Table 2.9 below display the projection trend in pollutions emission from agriculture (Use Energy) sector between 2010-2030 in baseline scenario. According to the table, carbon monoxides is a dominant pollution in agriculture and it increase over the years.

Table 2.10 Agriculture (use energy) emission by pollutants types between 2010-2030

No	Pollutants	Year				
		2010	2015	2020	2025	2030
1	Organic Carbon	0.04	0.05	0.05	0.05	0.06
2	Black Carbon	0.05	0.06	0.07	0.07	0.08
3	PM2.5	0.13	0.15	0.16	0.17	0.19
4	PM10	0.13	0.15	0.16	0.17	0.19
5	Sulfur-Dioxide	0.03	0.04	0.04	0.04	0.05
6	Nitrogen-Oxide	0.00	0.00	0.00	0.00	0.00
7	Non-Methane Volatile Organic Compounds	0.07	0.08	0.08	0.09	0.10
8	Methane	0.00	0.01	0.01	0.01	0.01
9	Carbon Monoxide	0.17	0.21	0.22	0.24	0.26
10	Carbon Dioxide	99.28	117.89	123.30	134.33	146.81

b) Agriculture (Non-Energy)

For the Agriculture in non-energy sector, the annual agricultural subsidiaries and industrial crop productions from 2010-2015 compiled by the MAFF is presented in Table 2.10. Default values of the fraction burnt (25% of each crop production) built-in LEAP for non-energy were adopted directly for all of crop categories/species except the fraction burnt for the rice straw burning with the rate of 23.7% for Cambodia case as reported in Thadalin et al. (2016) was used for rice straw burning.

Table 2.11 Subsidiaries and industry crop production in Cambodia 2010-2015, (tons)

Type	2010	2011	2012	2013	2014	2015
Rice	8,249,452	8,779,365	9,290,940	9,389,961	9,324,416	9,335,284
Mung bean	21,859	76,196	74,679	57,243	60,651	59,221
Soya bean	156,610	114,603	120,165	131,092	104,181	96,943
Maize	1,425,275	1,417,089	1,757,765	1,775,296	1,023,613	732,711
Jute	261	304	271	208	167	75
Cassava	4,248,942	8,033,843	7,613,697	7,933,382	11,943,204	13,298,109
Peanut	21,957	22,836	30,376	29,294	27,762	25,151
Sweet potato	79,347	46,648	48,754	50,543	848,629	45,425
Sesame	29,916	33,478	26,764	24,473	17,261	17,860
Sugarcane	355,830	468,738	1,573,772	911,333	1,540,997	709,176
Tobacco	14,625	12,861	8,987	8,814	13,939	8,058

Table 2.12 Agriculture (Non energy) emission by pollutants types between 2010-2030

No	Pollutants	Year				
		2010	2015	2020	2025	2030
1	Organic Carbon	1.41	1.74	1.85	2.01	2.20
2	Black Carbon	0.21	0.26	0.28	0.31	0.33
3	PM2.5	2.33	2.89	3.06	3.33	3.64
4	PM10	2.46	3.04	3.23	3.51	3.84
5	Ammonia	130.94	117.43	106.46	101.77	103.19
6	Sulfur-Dioxide	0.15	0.19	0.20	0.22	0.24
7	Non Methane Volatile Organic Compounds	2.04	2.30	2.45	2.67	2.91
8	Methane	275.91	229.67	185.11	152.31	128.71
9	Carbon Monoxide	25.97	32.48	34.39	37.47	40.95

The total pollution emission in agriculture (non energy) from 2010-2030, Table 2.12, were declined due to the reduction of dairy cattle (cow) have been decrease annually. As of 2010, the total methane emission was about 275.91 Thousand MT and dropped to about 128.71 Thousand MT according to the projection. For other pollution its almost stay still between 2010-2030.

c) Construction

Construction emissions are generated from activities associated during the construction phase of a project. Construction activities are typically short-term or temporary in duration. These activities include the operation of heavy on-road and off-road equipment for soil hauling and material delivery or soil disturbance, grading, moving, piling construction materials, open storage piles and both active and inactive disturbed surface areas. The emissions of criteria air pollutants and GHG may occur as a result of these related activities. Sometimes a project's construction-related emissions can have a significant impact with respect to air quality and/or global climate change.

The use of heavy equipment and earth moving operations during project construction can generate fugitive dust along with engine combustion emissions which may have substantial temporary impacts on local air quality. Particulate matter with a particle size that is less than ten microns in size (PM_{10}) can come from fugitive dust sources including open fields, roadways, storage piles, earthwork, etc. Fugitive dust emissions results from land clearing, demolition, ground excavation, cut and fill operations and equipment traffic usage on temporary roads at the construction site.

Table 2.13 Construction projects in Cambodia between 2009-2019

Whole of Cambodia				
Building type / Year	**Non-Residential (m^2)**	**Residential (m^2)**	**Industrial (m^2)**	**Commercial (m^2)**
2009	431,397.53	1,565,231.29	1,309,123.38	2,616,202.79
2010	359,847.58	1,469,659.50	614,798.80	144,913.85
2011	1,342,263.08	2,051,139.93	1,323,725.92	334,413.21
2012	456,914.25	2,682,426.19	2,008,477.74	1,166,469.06
2013	302,674.57	2,075,450.50	1,479,733.78	3,203,098.19
2014	364,107.71	3,165,690.93	1,725,902.96	977,353.07
2015	422,581.49	4,343,181.78	1,878,362.00	1,024,253.18
2016	443,972.79	6,321,557.00	2,239,579.00	5,603,580.00
2017	600,418.00	5,804,378.00	1,195,090.00	3,763,695.00
2018	2,784,873.00	5,182,768.00	884,631.00	3,512,496.00
2019	1,590,043.00	10,619,761.00	3,697,426.00	7,316,768.00

Source: Ministry of Land Management, Urban Planning and Construction

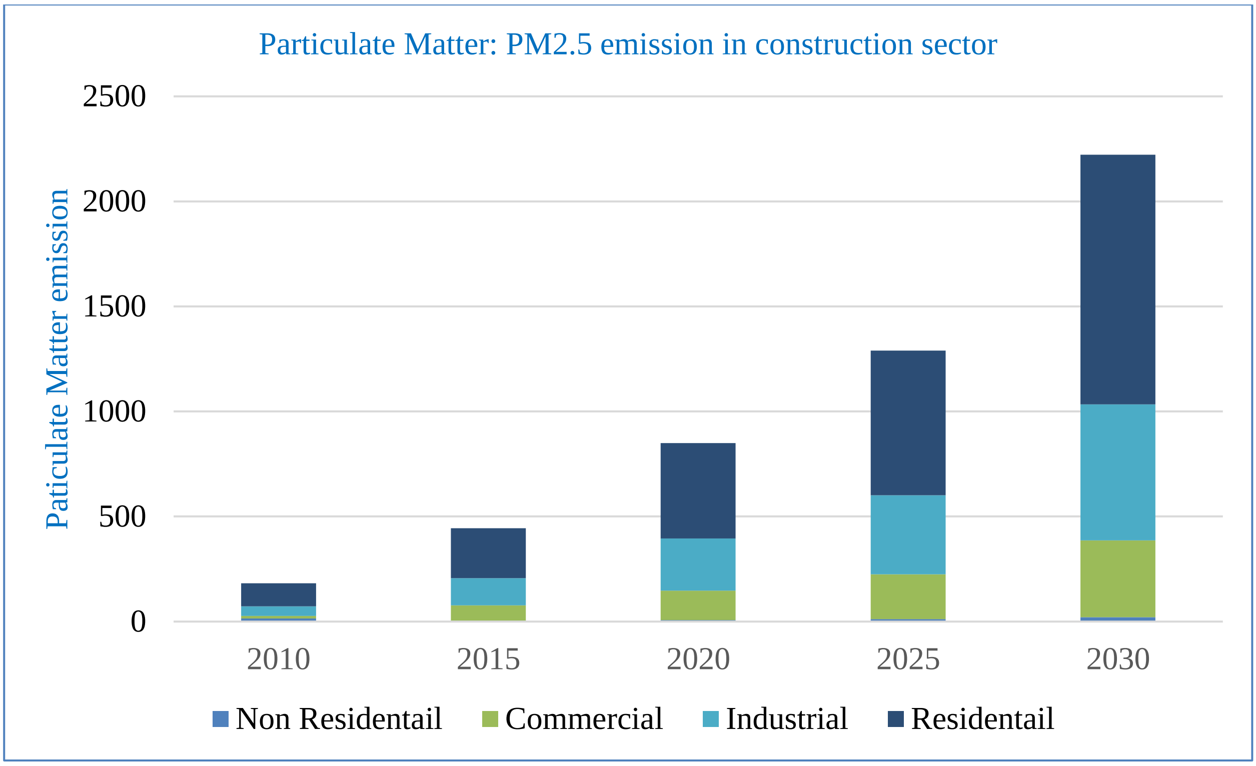

Figure 2.33 Progression of PM2.5 emission from construction sector between 2010-2030

Figure 2.33 above present about progression of PM2.5 emission from construction sector between 2010-2030. The main sources of PM2.5 emission was from Residential and it increase every year according to the projection of LEAP analysis.

d) Waste

For the waste sector, the sources of emissions are originating from the point of generation, waste management process and final disposal. By following the 2006 IPCC guideline, the sources of emissions are categorized into:

- Solid waste disposal
- Biological treatment of solid waste
- Incineration and open burning of waste
- Wastewater treatment and discharge

The waste generation and uncollected waste estimation were prepared using the number of population and waste generation per capita. The solid waste generation per capita was estimated at around 0.5 kg/day and roughly to be about 4 million tonnes as of 2015 and the uncollected wastes were estimated at about 87% of the total waste generation. From the National Institute of Statistics, the population in Cambodia are classified as Urban and suburban/rural area, the waste generation and uncollected waste are presented in Table 3.25. The amount of uncollected solid waste in suburban areas of Phnom Penh was calculated based on the percentage of collection coverage (83.3%) in Phnom Penh city reported in (IGES & UNEP, 2018). The waste disposal at the landfill for some provinces were reported in Sethy (2017) were used to justify the uncollected wastes in those provinces while the rest assumed all wastes are burnt after subtracting the incombustible compositions.

Table 2.14 below shows the trend in methane emission from waste sector between 2010-2030 in baseline scenario. Without any mitigation measure, there is a steady increase in methane emission estimated over the year especially from municipal waste burning in Cambodia. Figure 2.35 demonstrates the progression of the direct PM2.5 emission from uncontrolled waste burning over the years. From this analysis, it is clear that the waste sector is a major source of GHGs, SLCPs and air pollutants. In the waste sector, waste incineration is the dominant source of these emissions. The expected increase in emissions if driven by expected increases in population and waste generation.

Table 2.14 Waste sector emission by pollutants types between 2010-2030

Waste (Thousand MT)						
No	**Pollution**	**2010**	**2015**	**2020**	**2025**	**2030**
1	Organic Carbon	9.13	9.9	10.67	11.36	11.98
2	Black Carbon	1.13	1.23	1.32	1.41	1.49
3	PM2.5	16.99	18.42	19.84	21.13	22.29
4	PM10	20.62	22.36	24.09	25.65	27.06
5	Ammonia	1.94	2.11	2.27	2.42	2.55
6	Sulfur-Dioxide	0.87	0.94	1.01	1.08	1.14
7	Nitrogen-Oxide	8.5	9.21	9.92	10.57	11.15
8	Non-Methane Volatile Organic Compounds	39.16	42.47	45.74	48.72	51.38
9	Methane	6.34	6.88	7.41	7.89	8.32
10	Carbon Monoxide	65.84	71.4	76.91	81.91	86.4

3. MEASURES TO REDUCE EMISSIONS

The potential emissions reduction with the implementation of key existing government regulations, policies and strategies related to emission reduction were estimated using the LEAP-IBC tool. It is important that potential air pollution reduction are quantified for the mitigation measures in order to visualize the pollution scenario for developing effective actions. In particular, the Circular #01on "Measures to Prevent and Reduce the Ambient Air Pollution", the sub decree no.42 on "Control Air Pollution and Noise Disturbance", Climate Change Strategic Plan 2014-2023 and Cambodia's Updated Nationally Determined Contribution are the main existing government regulations and policies on emission reduction that are examined in this report. Moreover, additional essential clean air measures are also analyzed to visualize the potential emission reduction as for policy recommendation.

3.1 The Government Circular on Measures to Prevent and Reduce the Ambient Air Pollution

The circular on "Measures to Prevent and Reduce the Ambient Air Pollution" was issued in early 2020. The circular was developed to support the government goal on reducing air pollution in Cambodia for reflecting the recent increase of the Particulate Matter (PM10 and PM2.5) in urban areas of the country which poses a risk to the health of population. In the circular contains strategic measurements on reducing air pollution from the major sources and activities that led to the increasing of the concentration of Particulate Matter (PM10 and PM2.5) including the release of emissions from industrial, the uses of diesel-powered vehicles and other combustion fuels, wildfires, forest fires lawns, yard burning, garbage burning, open field burning of solid waste, waste landfills and construction sites. To be specific, there are 7 strategic measures including in this circular as following.

- The Administration of Construction Sites focuses on reinforcing the management of dust or particulate matter into the air and other discharges from pollutant sources such as construction sites, concrete production sites, transport of pebble sand, cement or other construction materials by means to require prior tire cleaning from the production sites
- The Quality Management of High Sulfur Content on Fuel focuses on promoting the implementation of sulfur standard level which contained in fuel for compliance with EURO standard (EURO III, IV, V).
- The Administration of Air Pollutants from Vehicles focuses on promoting the implementation of the emission standard on air pollutants from vehicles for compliance with EURO standard (EURO III, IV, V). Strengthening the traffic management in the capital, provinces, cities and towns through improving the efficiency of urban planning and reducing congestion and implementing prioritized strategies, public transportation and

enhancing the construction of motorcycle and pedestrian route systems are a part of this measure too.

- The Administration of Air Pollutants Emission from Production Sites focuses on promoting the technical installation of smoke and dust filters in the production sites in order to reduce the release of toxic gases into the air through the implementation of new technologies including using alternative clean energy from the use of natural gas, wind, hydropower, solar and biomass and promoting the use of clean coal sources that is not producing as much ash and low sulfur content (less than 1% sulfur content).
- The Administration of the Open-Field Waste Burning focuses on preventing and avoiding of all kinds of forest clearing, burning of garbage, burning solid waste in the open spaces, landfill and public squares and educating people to stop burning garbage, solid wastes, grasses, stalks and other agricultural wastes.
- The Improving Management and Improving the Urban Environment focuses on carrying out an environmental sanitation programs in the public areas and regularly clean the streets and expanding the green areas in building city and other surrounding areas that are under construction.
- The Establishment of Air Pollution Monitoring and Forecasting System focuses on installing the equipment for air quality monitoring in provincial and capital throughout the Kingdom of Cambodia and developing the action plans to create the monitoring system and giving an early warning for severe air pollution and to disseminate it to the public on time in order to prepare for any risks and health problems.

Table 3.1 Matrix of mitigation measures from Circular N. 01 in use for Development of Clean Air Plan

Mitigation Measures	Goals	Timeline
Sector: Construction		
Administration of Construction Site 1- Shall be reinforced the management of dust or particulate matter into the air and other transport of pebble sand, cement or other construction materials by means to require prior tier cleaning from the production sites, installation of high-pressure steam spray, and apply the proper tire cover before leaving out from the business sites in order to avoid	50% of all construction projects implement air pollution reduction measurement on administration of construction sites *(Assumption)*	2030

any spill or crumbs and dusty or particulate matter in to the roads. 2- Shall be reinforce the inspection and shall be strengthened the education to all construction site owners		
Sector: Transport		
The quality management of high sulfur content on fuel	1- Sulfur level to meet Euro III level 2- Sulfur level to meet Euro IV level 3- Sulfur level to meet Euro V level *(Government Circular)*	1- 2020 2- 2021 3- 2024
The Administration of Air Pollutants from Vehicles 1- Promoted the implementation of the emission standard on air pollutants from vehicles as the following: a. For car type - From 1st January 2022 onward, all kinds of new and used vehicles imported into the Kingdom of Cambodia must comply with the Standard in Type 4 (EURO IV) as stated in Annex II of this circular - From 1st January 2027 onward, all kinds of new and used vehicles imported into the Kingdom of Cambodia must comply with the Standard in Type 5 (EURO V) as stated in Annex II of this circular	1- Imported cars to meet Euro IV in 2022 2- Imported cars to meet Euro V in 2027 *(Government Circular)*	1- 2022 2- 2027
b. For Motorcycle and Tricycle Types - From 1st January 2023 with new and used motorcycle and tricycle that manufactured and imported into the	All imported motorcycles and tricycles to meet Euro III *(Government Circular)*	2023

Kingdom of Cambodia must comply with the Standard in Type 3 (Euro III) as stated in Annex III of this circular		
1- Implementing as prioritize with the public transport strategy and enhancing the construction of motorcycle and pedestrian route systems	Developing or improving public transport strategy and route systems to reduce air pollution *(Assumption)*	2030
2- There should be a plan to reduce the import of used vehicles and encourage the use of new vehicles and/or vehicles that use clean energy in order to eliminate the import of old vehicles	Reducing import of used cars 30% in 2030 *(Assumption)*	2030
3- Strengthening the management and monitoring the fuel quality and suppressing the production, sale and distribution of fuel products that do not meet fuel quality standards which have high sulfur content exceed the standard	Strengthening the management and monitoring the fuel quality of 80% of fuel station have to comply with EU standard *(Assumption)*	2030
Sector: Open waste burning		
The administration of the opened-field waste burning 1- Must have strategies to prevent and to avoid of all kinds of forest cleaning, burning of garbage, burning solid waste in the open areas, landfill and public squares 2- Must educating people to stop burning garbage, solid waste, grasses, stalks and other agricultural wastes	50% reduction of illegal opened waste burning across country through implementing air pollution reduction measurement on administration of air pollutants emission from opened-field waste burning *(Assumption)*	2030

3- If having severe forest fire, must immediately apply strategies through using all possible means in order to effectively extinguish the forest fire		

3.2 Sub Decree on Control of Air Pollution and Noise Disturbance

The sub decree on “Control of Air Pollution and Noise Disturbance” was issued in 2000. The sub decree was developed with purpose of protecting the environment quality and public health from air pollutants and noise pollution through monitoring, curb and mitigation activities. This sub-decree applies to all movable sources and immovable sources of air and noise pollution. In the sub decree there are 8 chapter and 39 articles where relates to provision on emission of air and noise pollution, pollution source monitoring, air pollution monitoring, inspection, emission standard and ambient air quality standard and so on.

Table 3.2 Matrix of mitigation measures from the sub decree in use for Development of Clean Air Plan

Mitigation Measures	Goals	Timeline
Sector: Industry		
Implementing industrial emission control	50% reduction in industrial emission as a result of implementation of emission control *(Assumption)*	2030

3.3 Cambodia Climate Change Strategic Plan (CCCSP) 2014-2023

The government strategic document “Cambodia Climate Change Strategic Plan 2014-2023” was issued in 2013. This document was developed with vision “Cambodia develops towards a green, low-carbon, climate-resilient, equitable, sustainable and knowledge-based society”. The strategy document determines 3 goals including:

- Reducing vulnerability to climate change impacts of people, in particular the most vulnerable, and critical systems (natural and societal);
- Shifting towards a green development path by promoting low-carbon development and technologies;
- Promoting public awareness and participation in climate change response actions.

The CCCSP 2014-2023 outlines 8 strategic objectives including:

- Promote climate resilience through improving food, water and energy security
- Reduce sectoral, regional, gender vulnerability and health risk to climate change impacts

- Ensure climate resilience of critical ecosystems (Tonle Sap Lake, Mekong River, coastal ecosystems, highlands, etc.), biodiversity, protected areas and cultural heritage sites
- Promote low-carbon planning and technologies to support sustainable development
- Improve capacities, knowledge and awareness for climate change responses
- Promote adaptive social protection and participatory approaches in reducing loss and damage due to climate change
- Strengthen institutions and coordination frameworks for national climate change responses
- Strengthen collaboration and active participation in regional and global climate change processes

Table 3.3 Matrix of mitigation measures from CCCSP in use for Development of Clean Air Plan

Mitigation Measures	Goals	Timeline
Sector: Residential		
1- Promote and installing fuel efficiency stove in rural areas 2- Promote using bio-gas for cooking in rural areas	1- 60% of residential in rural switch from using less efficiency stoves 2- 60% of residential in rural switch from using bio-mass to bio-gas *(Assumption)*	1- 2030 2- 2030

Table 3.4 Matrix of recommended mitigation measures in use for Development of Clean Air Plan

Mitigation Measures	Goals	Timeline
Sector: Charcoal Making		
Improve efficiency of charcoal production	Charcoal kiln efficiency increase from 11% to best available 30% efficiency *(Assumption)*	2030
Sector: Transport		
1- Freight transport implementing Euro IV standards 2- Passenger transport, all buses implementing Euro IV	1- All new heavy-duty vehicles meet Euro IV standards from 2022	1- 2022 2- 2022

	2- All new buses meet Euro IV standards from 2022 *(Assumption)*	

3.4 Cambodia's Updated Nationally Determined Contribution

The government strategic document "Cambodia's Updated Nationally Determined Contribution" was issued in 2020. This document was developed to presents Cambodia commitments and needs for the next decade, in order to realize her vision of a low carbon and resilient society. This strategic document showcased her progress in climate policy, and put forward mitigation targets and adaptation actions consistent with the national circumstances of Cambodia.

Table 3.5 Matrix of mitigation measures from NDC in use for Development of Clean Air Plan

Mitigation Measures	Goals	Timeline
Sector: Electricity Generation		
Energy Efficiency - Application of electrical equipment's labeling and Minimum Energy Performance Standards (lighting, cooling and equipment) - Improvement of process performance of energy efficiency by establishment of energy management in building/industries - Public awareness campaigns on energy saving - Building codes and enforcement/certification for new buildings and those undergoing major renovation - Introduction of efficient electrical motors and boilers	- Energy efficiency in residential sector improves by 31.7% - Energy efficiency in commercial and public services sector improves by 41.7% - Energy efficiency in industry sector improve by 2.3% *(Assumption)*	2030

3.5 Emission Reduction from Priority Air Pollution Measures

Table 3.6 Summary of baseline and nationally avoided emission

Whole of Cambodia (Thousand MT)											
	Organic Carbon	Black Carbon	PM2.5	PM10	Ammonia	Sulfur-Dioxide	Nitrogen-Oxide	Non-Methane Volatile Organic Compounds	Methane	Carbon Monoxide	Carbon Dioxide
Baseline emissions 2030/Unit	44.97	14.57	98.50	132.42	112.00	70.05	328.96	1,119.21	218.22	2,725.61	40,150.82
Air Pollution Circular Measures 2030/Unit	21.98	9.26	53.19	74.18	108.13	59.00	286.36	315.91	194.95	1,127.17	39,420.31
All Measures 2030/Unit	17.20	5.33	38.71	59.36	107.31	33.55	171.04	230.75	165.28	878.98	32,689.07
Total Emission Reduction (Baseline Emission - Air Pollution Circular Measures)	23.00	5.31	45.31	58.24	3.87	11.05	42.60	803.30	23.27	1,598.45	730.51
% Reduction	51.14	36.43	46.00	43.98	3.45	15.78	12.95	71.77	10.66	58.65	1.82
Total Emission Reduction (Baseline Emission - All Measure)	27.77	9.24	59.80	73.06	4.69	36.50	157.92	888.46	52.94	1,846.63	7,461.75
% Reduction	61.75	63.43	60.71	55.17	4.19	52.10	48.01	79.38	24.26	67.75	18.58

By applying LEAP-IBC calculation based on the best available data, the estimation of air pollutant emission scenario in 2030 and the potential emission reduction through implementing measures are illustrated. According to the above table, the baseline emission in 2030 (Business as Usual Scenario) are highlighted summary, the highest air pollutants emitting in 2030 is CO_2 (40,150.82Thousand MT) following by CO (2,725.61Thousand MT). For particular matter PM2.5 and PM_{10} are estimated increasing up to 98.5Thousand MT and 132.42Thousand MT, respectively. Other key air pollutants are also presented such as Black Carbon = 14.57 Thousand MT, SO_2 = 70.05 Thousand MT, NO_2 = 328.96 Thousand MT.

To implement air pollution measures according to the circular no.01on “Measures to Prevent and Reduce the Ambient Air Pollution, the air pollutant emission can reduce dramatically. Especially, for PM2.5, PM_{10} and CO which the volume of them is reduced by half. Besides, the implementation of measures taking from the sub decree, Cambodia Climate Change Strategic Plan and Cambodia’s Updated Nationally Determined Contribution result in additional reduction in all air pollutants. To combine with all measures, air pollutant emission is cut significantly with a cutting rate of 59.8 Thousand MT (60.71%) for PM2.5, 73 Thousand MT (55.1%) for PM10, 9.3 Thousand MT (63.69%) for Black Carbon, 36.5 Thousand MT (52.14%) for SO2, 158 Thousand MT (48.02%) for NO2 and 7,461.7 Thousand MT (18.58%) for CO2.

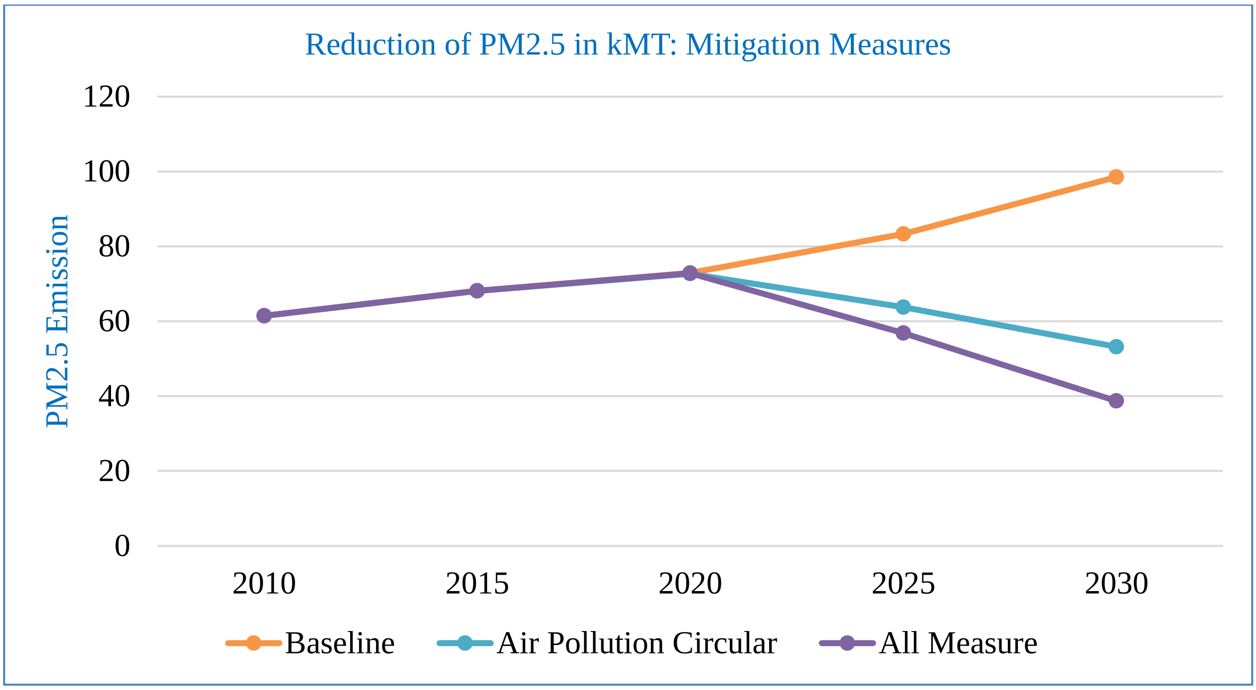

Figure 3.1 Reduction of national PM2.5 emissions from measures

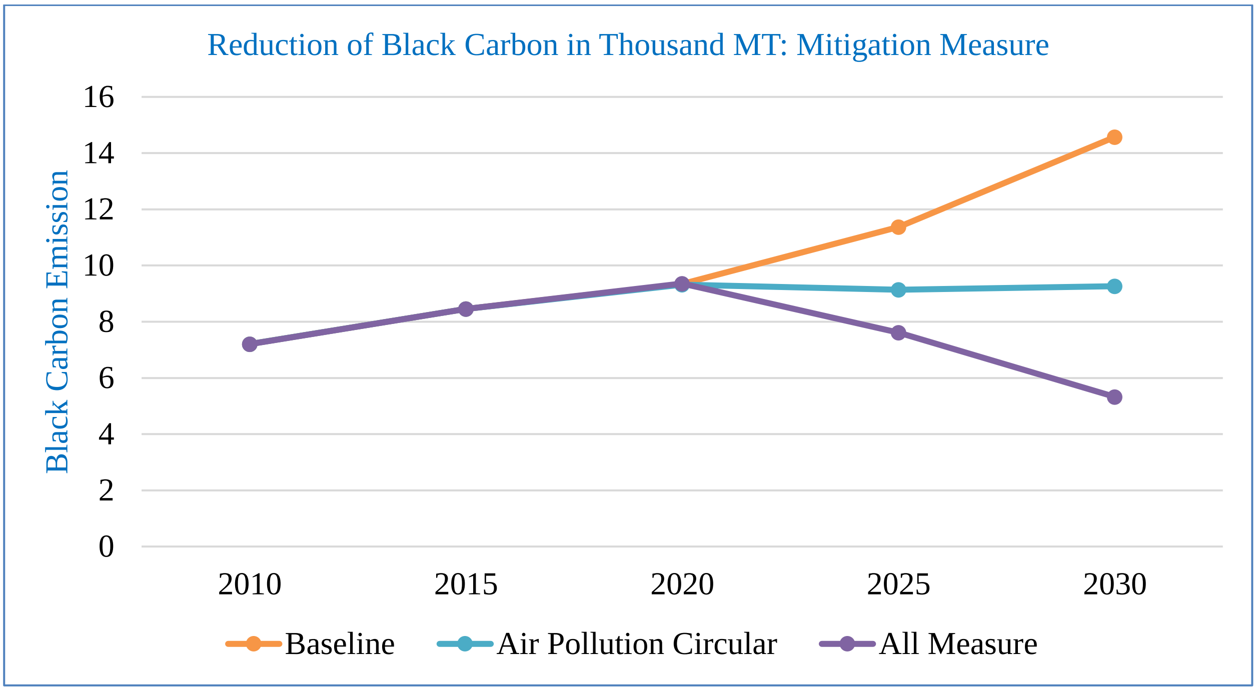

Figure 3.2 Reduction of national black carbon emissions from measures

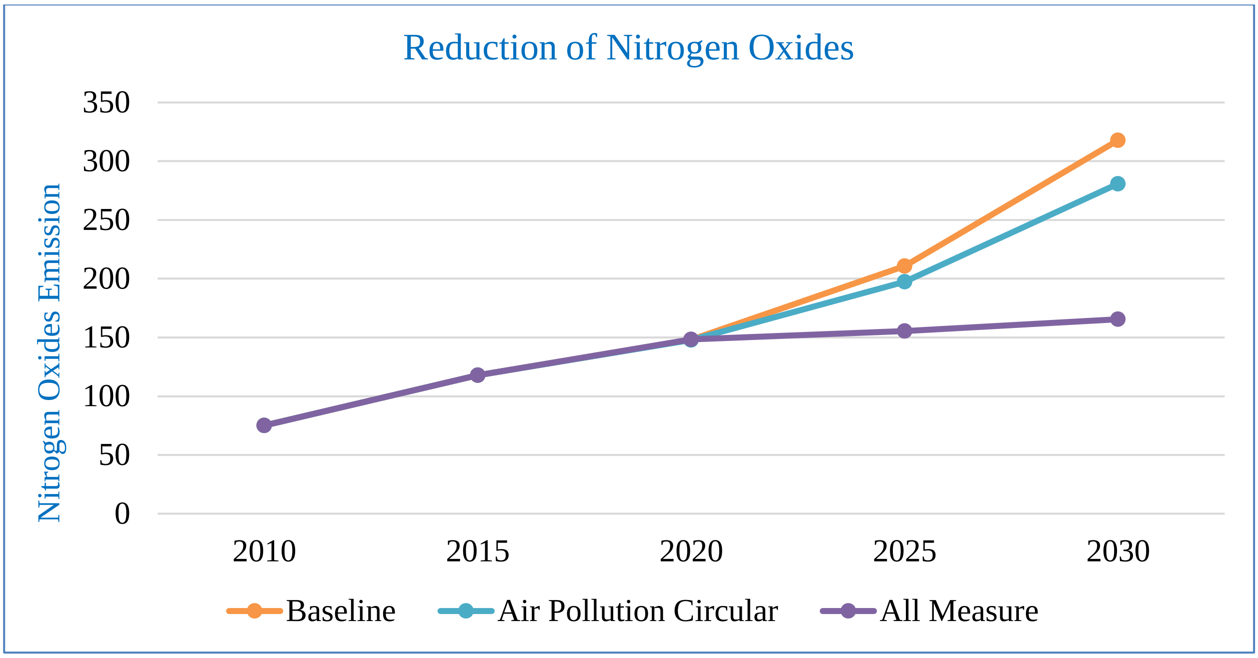

Figure 3.3 Reductions of national nitrogen oxide emissions from measures

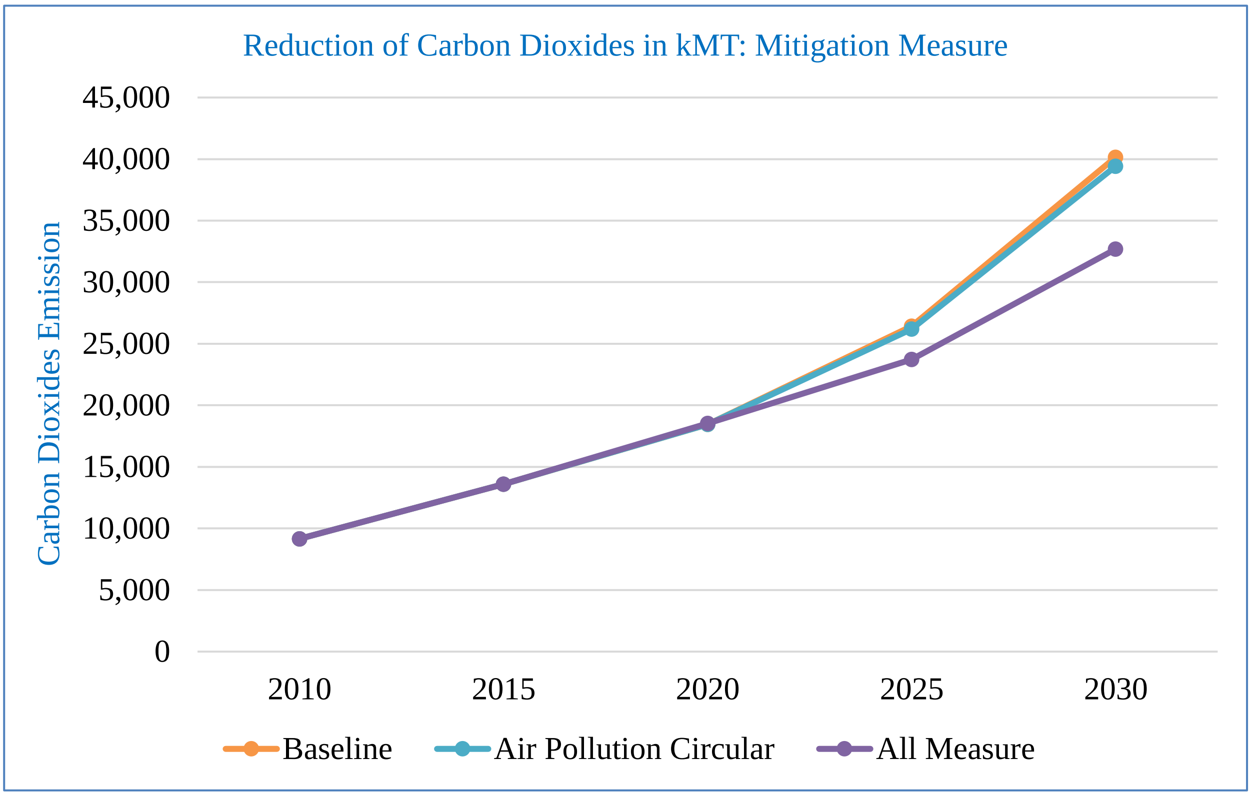

Figure 3.4 Reduction of carbon dioxide from measures

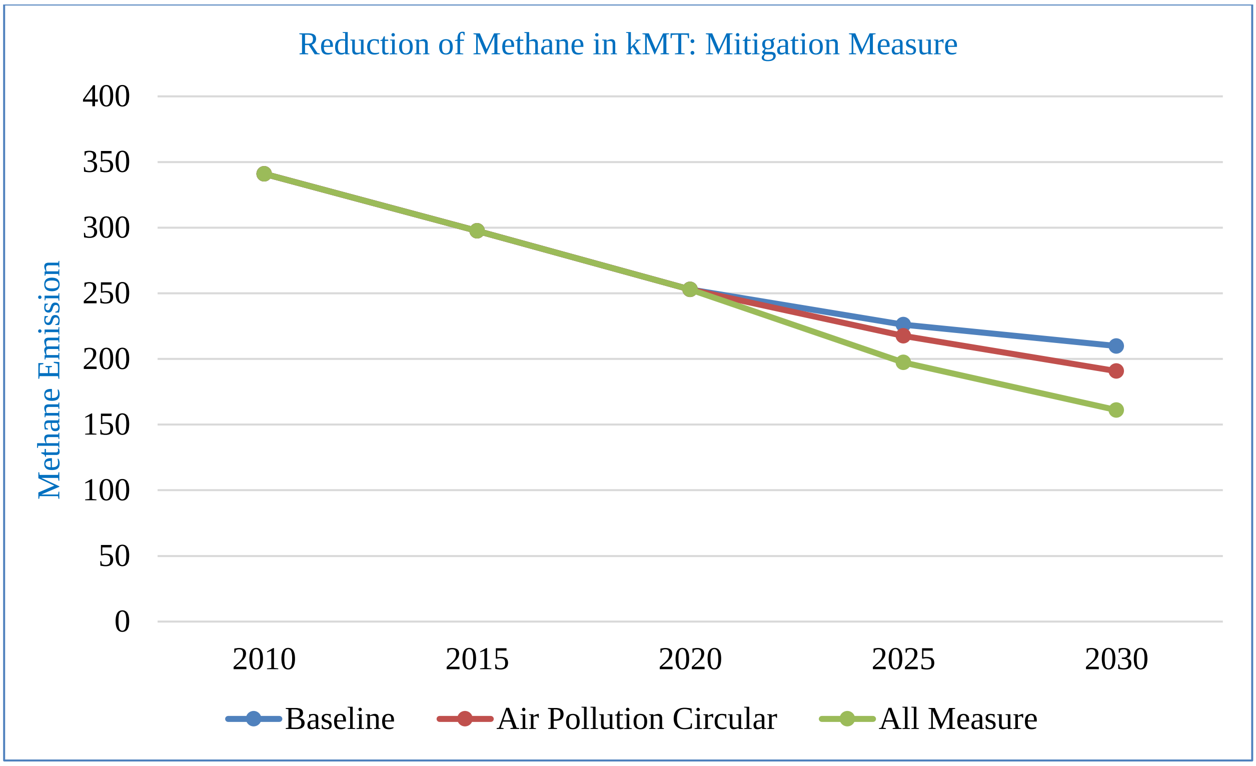

Figure 3.5 Reduction of methane from measures

3.6 Expected changes in air pollution concentration and impacts

According to the table 3.6 "Summary of baseline and nationally avoided emission" above, the implementation of the mitigation measures as targeted in the plan could make a significant reduction in emission of air pollutants, short-lived climate pollutants and greenhouse gases. The effect that these emission reductions would have on the concentration of fine particulate matter (PM2.5) in Cambodia, and the health impacts associated with exposure to PM2.5 depends on several factors.

The first factor is the contribution of emissions from activities to PM2.5 concentrations in Cambodia. Besides, the human and economic activities within the country the source of emission pollutants can contribute from international shipping, natural sources and the transport of emissions from other countries. Meanwhile, the implementation of emission reduction measures in Cambodia can lead to a substantial contribution to reducing PM2.5 and other air pollutants; regional emission reductions can also make a significant contribution to achieving this as well if according to WHO air quality guidelines.

To monitor air quality and especially PM2.5 concentration in ambient air, Cambodia is installing air quality monitoring equipment. Although the installation of air quality equipment and stations is still a need of the government, so far Cambodia installed 44 air quality monitoring equipment across cities central of all provinces. According to 2019 annual report from General

Director of Environmental Protection, the concentration of PM2.5 ranges from 8 to 50µm/m^3 with the annually average concentration of 21.30µm/m^3 (standard 25µm/m^3/year).

The second factor that determines how the implementation of those measures will affect PM2.5 concentration in Cambodia is the contribution that emissions of black carbon, organic carbon, NO_x, SO_2, NH_3 and natural sources make to PM2.5 concentration in the nation. Presently, there is no study of the composition of PM2.5 to understand this contribution. Yet, the calculation from LEAP-IBC shows that each of these air pollutants would be significantly reduced (10-60% in 2030 compared to the baseline scenario) by executing these measures, and therefore a reduction in PM2.5 concentration would be expected.

Finally, the third factor that determines the effectiveness of these measures is the relationship between exposure to air pollution and negative health impacts in Cambodia. Although there is limitation of research on the linkage between air pollution and public health in Cambodia. However, according to WHO there is evidence of harmful health effects at even very low levels of PM2.5 exposure; and that in the absence of a threshold for harmful health effects, public health will benefit from any reduction in PM2.5 concentrations (The Regional Office for Europe of the World Health Organization, 2013). This refers that by implementing all emission reduction measures will improve public health in Cambodia.

3.7 Air Pollution Human Health Benefits

Exposure to air pollution, in particular fine particulate matter (PM2.5), is associated with substantial health impacts, primarily through respiratory and cardiovascular diseases (Murray et al., 2020). PM2.5 air pollution is both directly emitted to the atmosphere, in the form of black carbon, organic carbon, and dust particulates, and is also formed in the atmosphere from the emission of gaseous air pollutants including Nitrogen Oxides, Sulphur Dioxide, Ammonia and NMVOCs. Long-term exposure to elevated PM2.5 concentration significantly increases the risk of premature death. As a consequence of the emission reductions shown in Section IV from the implementation of the mitigation measures included in Cambodia's Clean Air Plan, the exposure of Cambodians to health-damaging levels of air pollutants would be decreased.

To quantify the health benefits that could result from the implementation of the mitigation measures included in Cambodia's Clean Air Plan, an air pollution health impact assessment was undertaken. In the ambient air pollution health impact assessment methods implemented in the LEAP tool (explained in detail in Kuylenstierna et al., 2020), the health endpoint for which the impact of ambient (i.e. outdoor) PM2.5 exposure is estimated is premature mortality. Premature mortality attributable to PM2.5 exposure is estimated for children (less than 5 years) and adults (>30 years) in − 5- year age groups (30–34, 35-39…75-79, >80 years) from 5 disease categories (children: acute lower respiratory infection; adults: chronic obstructive pulmonary disease, ischemic heart disease, cerebrovascular disease and lung cancer). The metric used to quantify exposure to ambient air pollution is the national population-weighted annual average ambient PM2.5 concentration, i.e. the average exposure across all Cambodians, averaged across the year. This metric is an indicator of long-term exposure to ambient PM2.5 concentrations. While there are important health impacts that occur due to short-term (i.e. acute) exposure to PM2.5, the health burden is substantially higher for the long-term (i.e. chronic) exposure (REVIHAAP, 2013). The overall methodology for quantifying the health impacts of the different emission scenarios in LEAP is shown in Figure 3.6.

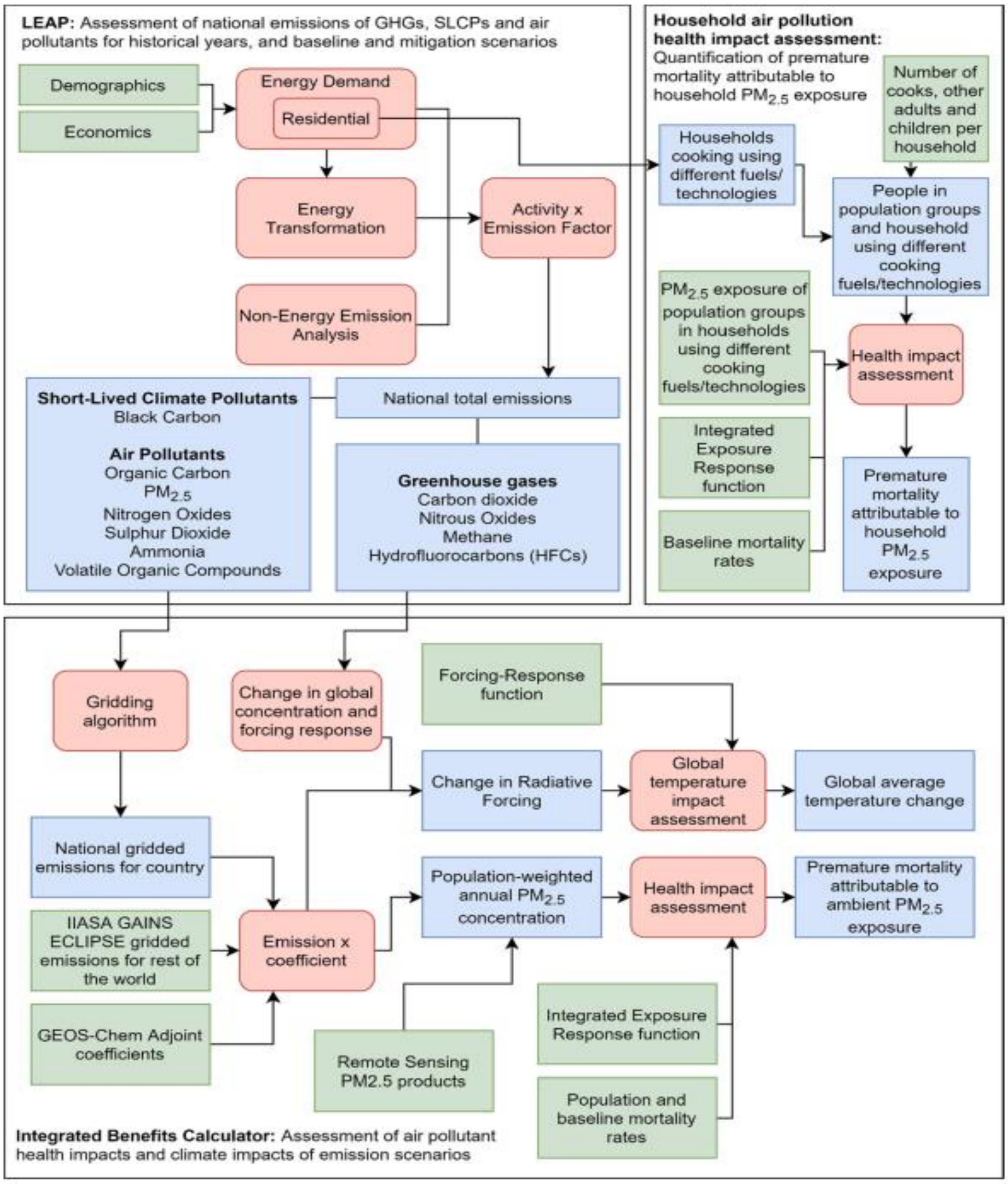

Fig. 1. Schematic of LEAP-IBC framework for estimating emissions for different scenarios and the resultant population-weighted annual average $PM_{2.5}$ concentration, health impacts, and impact on global average temperature change. Key inputs are shown in green, calculations in red, and outputs in blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Figure 3.6 Overview of LEAP-IBC calculation framework for air pollution health impact assessment (source: Kuylenstierna et al. 2020).

To quantify premature mortality attributable to ambient PM2.5 exposure for each population group and each disease category, national population-weighted annual average PM2.5 concentrations were combined with 'integrated exposure response' (IER) functions that have previously been extensively used for quantifying air pollution health burdens (Burnett et al., 2014; Cohen et al., 2017). The IER functions (Equation 1) quantify the relative risk (RR) for mortality from specific diseases for PM2.5 exposures up to very high levels (up to 10,000 μg m-3), by integrating RRs derived from epidemiological studies between cause-specific mortality and PM2.5 exposure from ambient air pollution, household air pollution, second hand smoke, and active smoking.

$$RR_{IER} = 1 + \alpha\left(1 - e^{-\gamma\left(z - z_{cf}\right)^{\delta}}\right) \qquad \text{Eq. 1}$$

Where zcf is the PM2.5 low concentration cut-off, z is the PM2.5 concentration that a population is exposed to, and α, δ, and γ are IER-specific parameters (Burnett et al., 2014; Cohen et al., 2017). The RR derived from the IER function for a particular disease and age group, is then used in combination with the baseline mortality rate for that disease for the population in the target country, and the exposed population in the age category in the target country to estimate the number of premature deaths attributable to ambient PM2.5 exposure from the particular disease in that age group (Equation 2).

$$\Delta \text{Mort} = y_0 \left(\frac{RR_{IER} - 1}{RR_{IER}}\right) Pop \qquad \text{Eq. 2}$$

Here y0 is the baseline mortality rate for each disease category, and Pop is the exposed population for each child or adult age category. Baseline mortality rates for each disease category were taken from the Global Burden of Disease Results tool (http://ghdx.healthdata.org/gbd-results-tool).

Population-weighted annual average PM2.5 concentrations were estimated by combining the emissions estimated in LEAP for each PM2.5 and PM2.5-precursor pollutant with outputs from an atmospheric chemistry transport model, GEOS-Chem Adjoint. National total emissions of primary PM2.5 (black carbon, organic carbon and other primary PM emissions), and secondary inorganic PM2.5 precursors (NOx, SO2 and NH3) derived using LEAP for the target country are spatially distributed into 2 o x 2.5o grids covering the country to match the scale of the GEOS-Chem Adjoint model results (see below). The proportion of national total emissions of each pollutant assigned to the 2 o x 2.5o grids covering the country was based on the spatial distribution of emissions across Cambodia in an existing gridded emission dataset, the IIASA GAINS ECLIPSE emissions dataset (Stohl et al., 2015). The ECLIPSE estimates emissions of SLCPs and air pollutants for historical and future projections in 0.5o grids globally. For those grids that cover the target country, the ECLIPSE emissions were apportioned by population (based on Gridded

Population of the World v3 dataset (CIESIN, 2005)). This ensured that the LEAP-derived emissions only replace the emissions associated with the target country. Emissions from the rest of the world are represented by the gridded ECLIPSE emissions outside of the target country.

Next, to translate gridded emissions to population-weighted annual average PM2.5 concentrations, accounting for transport and chemical processing in the atmosphere, the gridded emissions are then combined with parameterized output from the adjoint of the GEOS-Chem global atmospheric chemistry transport model (Bey et al., 2001; Henze et al., 2007). The GEOS-Chem Adjoint model output quantifies the relationship between emissions of a particular pollutant that contributes directly to PM2.5 (BC, OC or other PM), or is a precursor to PM2.5 (NOx, SO2 and NH3) in any location, and the associated change in PM2.5 in the target country. GEOS-Chem simulates the formation and fate of pollutants globally at a grid resolution of 2° × 2.5°, with 47 vertical levels. Emissions of aerosols and aerosol precursors include both natural (i.e., ocean, volcanic, lightning, soil, biomass burning, biogenic and dust) and anthropogenic (transportation, energy, residential, agricultural, etc.) sources. The adjoint of the GEOS-Chem model calculates the sensitivity of a particular model response metric (in this case population-weighted annual average surface PM2.5 concentration across the target country) with respect to an emission perturbation in any of the global model 2° × 2.5° grid cells (Henze et al., 2007), accounting for all of the mechanisms related to aerosol formation and fate. These sensitivities are output from the GEOS-Chem adjoint as gridded 'coefficients', which are then multiplied by emission estimates in IBC to estimate the change in population-weighted annual average PM2.5 concentrations in Cambodia for each year and emission scenario.

Adjoint coefficients were produced for each pollutant that contributes to population-weighted annual average PM2.5 concentrations, namely, BC, OC, NOx, SO2, NH3 and other PM (in this case, predominantly mineral dust), reflecting their different reactivity and formation pathways in the atmosphere. The adjoint coefficients are applied by multiplying, in each grid and for each pollutant, the coefficient by emissions, and summing across all grids to estimate the change in PM2.5 for a particular year for a particular scenario.

Population-weighted annual average PM2.5 concentrations is combined with Equations 1 and 2 to estimate the number of premature deaths attributable to ambient air pollution for each year and emission scenario. Premature mortality attributable to ambient PM2.5 exposure was estimated for 2015, and for 2030 for the baseline scenarios and for the scenario that reflect the implementation of mitigation measures.

In 2015 population-weighted annual PM2.5 concentrations were estimated to be ~21 µg m-3 in Cambodia (Figure 3.7), more than twice the World Health Organization international air quality guideline value. As shown in Figure 3.7 below, a large fraction of this PM2.5 concentration is estimated to result from emissions in other countries that is transported to Cambodia, with 22% of PM2.5 exposure estimated to result from national emissions emitted in Cambodia. This total exposure to PM2.5 concentrations was estimated to result in 3,100 premature deaths in 2015 (Figure 3.9), primarily affecting older people, with also resulting in ~500 infant deaths in 2015, 17% of the total number of premature deaths. In the baseline projection, both annual PM2.5 exposure, and premature deaths were estimated to increase in 2030 compared to 2015 levels, with an annual exposure of 24 µg m-3 in 2030 in the baseline scenario, a 14% increase compared to 2015 levels. Premature deaths were projected to increase to 5700 per year in 2030, an 83% increase. The larger relative increase in health burden from air pollution exposure compared to the increase in PM2.5 concentrations is due to the larger, and older population exposed to air pollution in 2030 compared to 2015 levels.

The full implementation of Cambodia's Clean Air Plan was estimated to reduce population-weighted PM2.5 concentrations by 4 µg m-3 in 2030 compared to the baseline scenario, a 17% reduction in total population-weighted PM2.5 concentrations in 2030 compared to the baseline scenario. This reduction is also a 57% reduction in the contribution of Cambodia's emissions to PM2.5 concentrations in Cambodia. This reduction in PM2.5 concentrations across Cambodia would avoid almost 900 (878) premature deaths per year, 15% of the total health burden from air pollution, and 57% of the health burden caused by emissions from Cambodia itself.

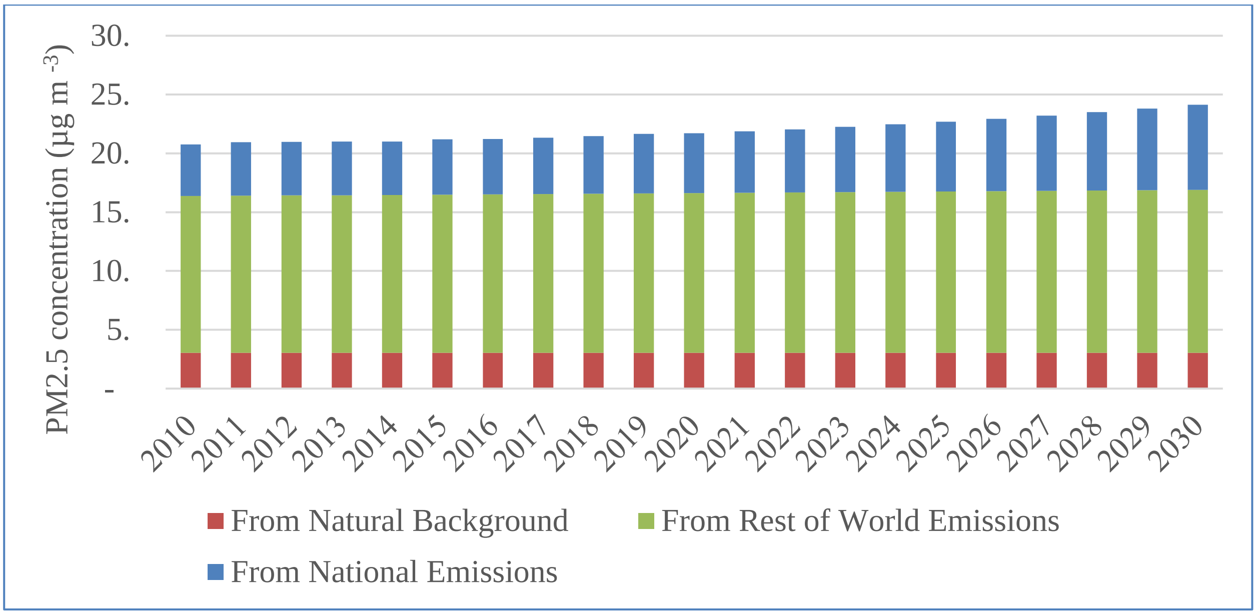

Figure 3.7 Population-weighted PM2.5 concentrations for Cambodia from LEAP-IBC for 2010-2030 for the baseline scenario

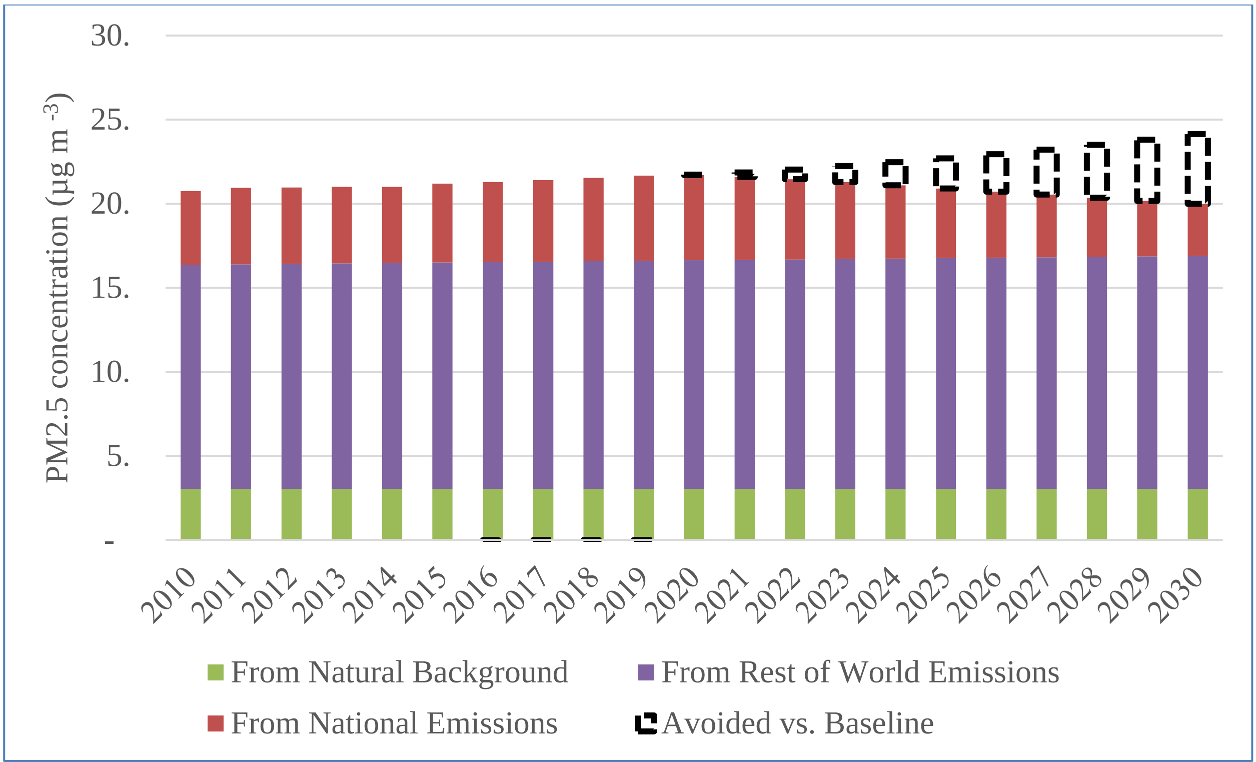

Figure 3.8 Reduction in population-weighted PM2.5 concentrations for Cambodia from LEAP-IBC for 2010-2030 from the implementation of all measures included in Cambodia's Clean Air Plan, compared to the baseline scenario

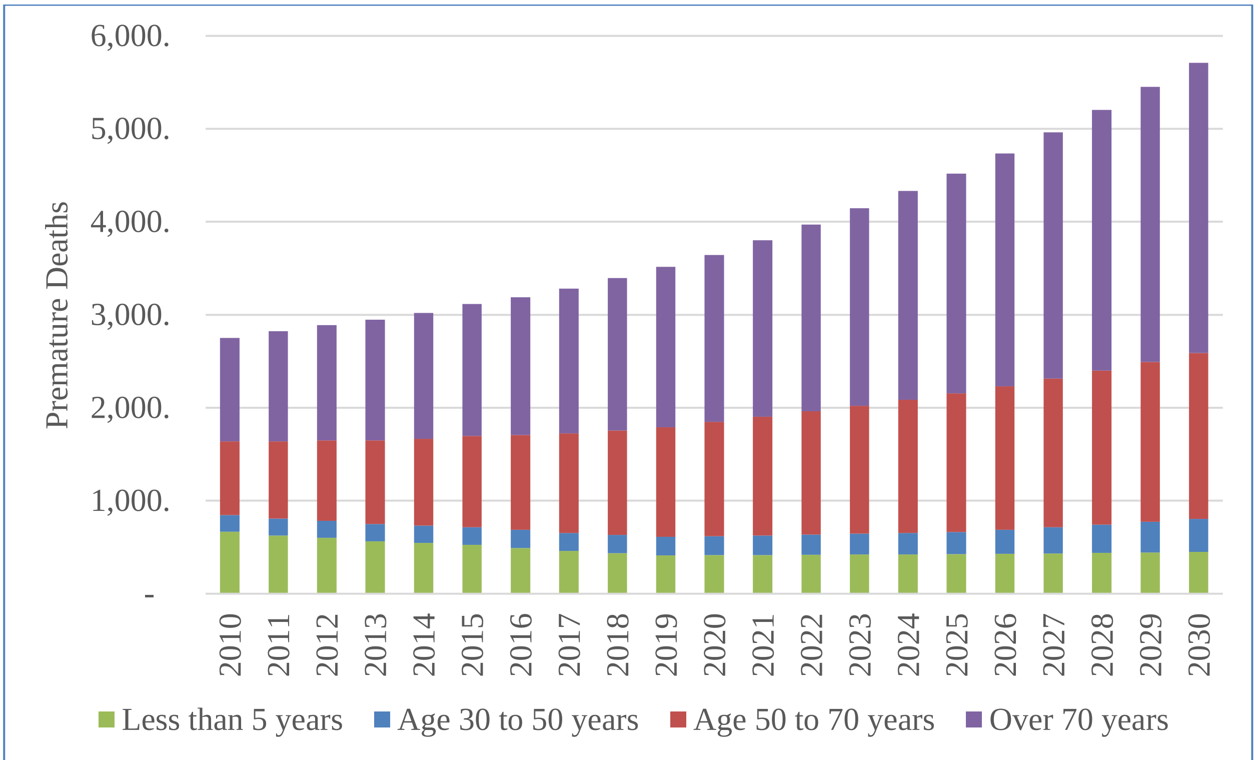

Figure 3.9 Premature deaths attributable to ambient PM2.5 exposure in Cambodia from LEAP-IBC for 2010-2030 for the baseline scenario

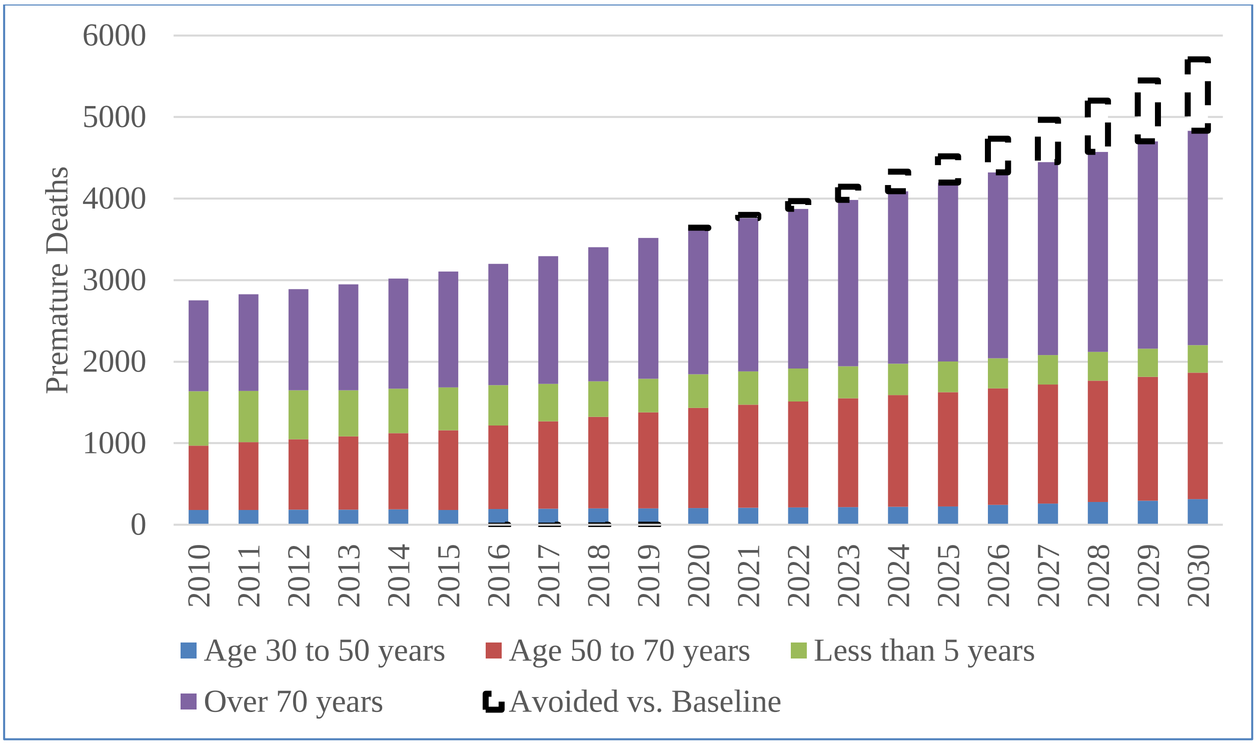

Figure 3.10 Premature deaths attributable to ambient PM2.5 exposure in Cambodia from LEAP-IBC for 2010-2030 from the implementation of all measures included in Cambodia's Clean Air Plan, compared to the baseline scenario

4. ACTION PLAN TO REDUCE AIR POLLUTION

In this section, the implementation of mitigation measures is broken down into several sectorial actions to tell in what extent the measures could contribute to the reduction of emission, including the emissions of air pollutants, short-lived climate pollutants and/or greenhouse gases. Each measure focus on the main sources of pollution such as transport, industrial, residential, construction and waste sectors. In Air Pollution Circular Measure, there is a measure for an alternative energy option. However, there appear to be some challenges due to insufficient of resource, both human and financial resource.

4.1 Emission Control from Transportation

The emission is associated with a wide range of negative health effects, including premature mortality due to respiratory and cardiovascular diseases, and lung cancer, and non-fatal health outcomes including asthma and other respiratory conditions in adults and children. In their most recent comprehensive review of health effects of air pollution. To cope with this, the administration of air pollutants from vehicles, fuel quality is required.

Table 4.1 Mitigation measures apply for transportation sector

Mitigation Measures	Goals	Timeline
Circular #01 on Measures to Prevent and Reduce the Ambient Air Pollution		
The quality management of high sulfur content on fuel	1- Sulfur level to meet Euro III standard 2- Sulfur level to meet Euro IV standard 3- Sulfur level to meet Euro V standard *(Government Circular)*	1- 2020 2- 2021 3- 2024
The Administration of Air Pollutants from Vehicles 1- Promoted the implementation of the emission standard on air pollutants from vehicles as the following: a. For car type - From 1st January 2022 onward, all kinds of new and used vehicles imported into the Kingdom of Cambodia must comply with the Standard in Type 4 (EURO IV) as stated in Annex II of this circular - From 1st January 2027 onward, all kinds of new and used vehicles imported into the Kingdon of Cambodia must comply with the Standard in Type 5 (EURO V) as stated in Annex II of this circular	1- Imported cars to meet Euro IV in 2022 2- Imported cars to meet Euro V in 2027 *(Government Circular)*	1- 2022 2- 2027

b. For Motorcycle and Tricycle Types - From 1st January 2023 with new and used motorcycle and tricycle that manufactured and imported into the Kingdom of Cambodia must comply with the Standard in Type 3 (Euro III) as stated in Annex III of this circular	All imported motorcycles and tricycles to meet Euro III *(Government Circular)*	2023
2- Implementing as prioritize with the public transport strategy and enhancing the construction of motorcycle and pedestrian route systems	Developing or improving public transport strategy and route systems to reduce air pollution *(Assumption)*	2030
3- There should be a plan to reduce the import of used vehicles and encourage the use of new vehicles and/or vehicles that use clean energy in order to eliminate the import of old vehicles	Reducing import of used cars 30% in 2030 *(Assumption)*	2030
4- Strengthening the management and monitoring the fuel quality and suppressing the production, sale and distribution of fuel products that do not meet fuel quality standards which have high sulfur content exceed the standard	Strengthening the management and monitoring the fuel quality of 80% of fuel station have to comply with EU standard (Assumption)	2030
Additional recommended measure		
1- Freight transport implementing Euro IV standards 2- Passenger transport, all buses implementing Euro IV	1- All new heavy-duty vehicles meet Euro IV standards from 2022 2- All new buses meet Euro IV standards from 2022 *(Assumption)*	1- 2022 2- 2022

With the implementation of the mitigation measures in the transport sector with extending the mitigation measures to cover not only passenger vehicle but the freight transport and public transport, it is estimated that the emissions from transport sector will be reduced by 78.32 %, 73.51 %, 46.61% and 7.90% for PM2.5, black carbon, NOx and CO_2 respectively.

Table 4.2 Emission reductions for transport mitigation measures by pollutant

Transport (Thousand MT)											
Branches	**Organic Carbon**	**Black Carbon**	**PM2.5**	**PM10**	**Ammonia**	**Sulfur-Dioxide**	**Nitrogen Oxide**	**Non-Methane Volatile Organic Compounds**	**Methane**	**Carbon Monoxide**	**Carbon Dioxide**
Baseline emissions (2030)	9.07	5.93	21.35	21.35	0.57	8.15	268.50	805.42	7.87	1,818.19	27,497.56

Air Circular Measures (2030)	1.71	4.14	9.89	9.89	0.88	0.33	238.71	116.98	4.98	519.74	26,722.11
All Measures (2030)	1.41	1.57	4.63	4.63	0.88	0.33	143.35	104.44	4.91	485.82	25,325.62
Emission reduction (Baseline emissions - Air Circular Measures)	7.36	1.80	11.46	11.46	-0.31	7.82	29.78	688.43	2.89	1298.45	775.45
% Reduction	81.13	30.32	53.67	53.67	-54.75	95.90	11.09	85.48	36.71	71.41	2.82
Emission reduction (Baseline emissions - All Measures)	7.66	4.36	16.72	16.72	-0.31	7.82	125.15	700.97	2.96	1,332.37	2,171.94
% Reduction	84.43	73.51	78.32	78.32	-54.75	96.00	46.61	87.03	37.64	73.28	7.90

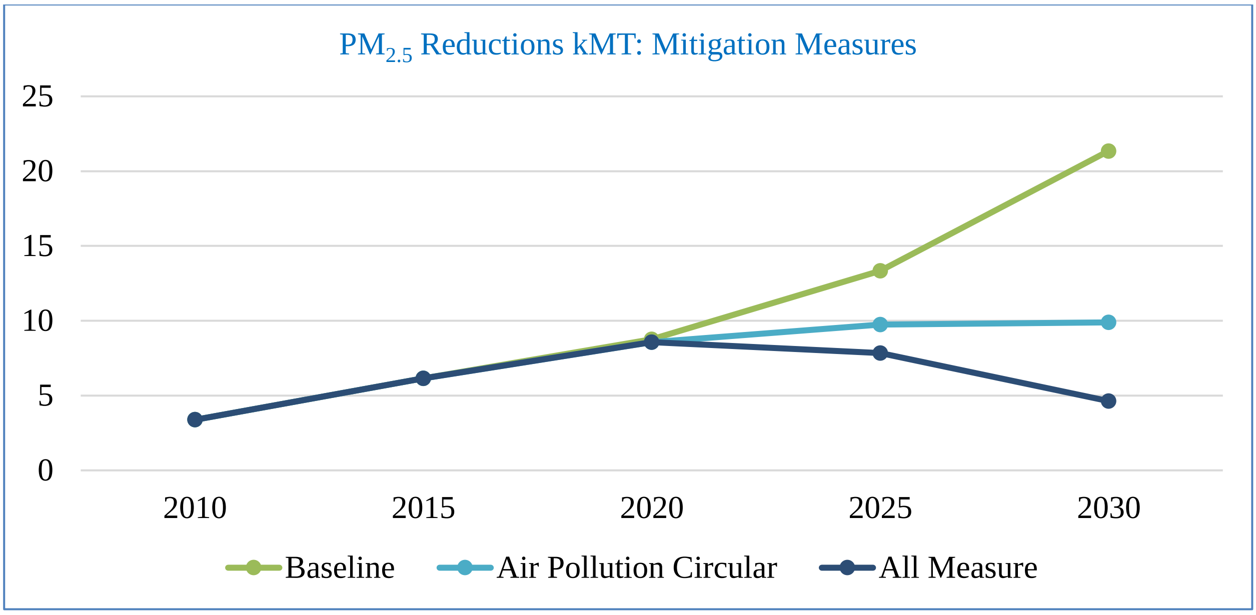

Figure 4.1 PM2.5 reductions from transport measures

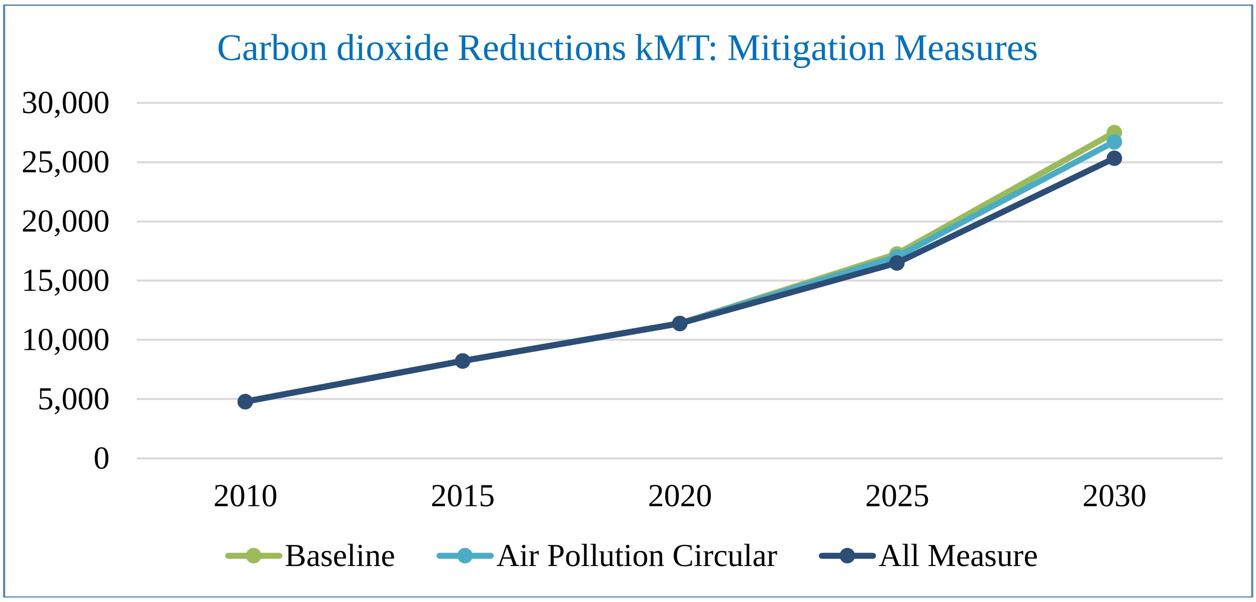

Figure 4.2 Carbon dioxide reductions from transport measures

4.2 Emission Control from Industries and Handicrafts

Cambodia is not heavily industrialized country and most of the industries are garment factories. There is also light industry such as food and beverages, wood products, rubber manufacturing, etc. and by 2020, the 796 factories in Phnom Penh. Several fuel types (coal, petroleum products, biomass, and electricity) is used for the industrial sector. The coal consumption is an increasing trend over time due to the investment on the thermal coal power plant in Cambodia and expecting in a growing trend in the future. Industrial development is one of the key factors for economic development of Cambodia which is, to some extent, leading to increase the level of air pollution such as SO_x, NO_x, CO etc.

In order to protect the human health and minimize the impact on the environment, emission control from the industrial sector is required, thus the prevention and end-of-pipe control is needed. The prevention focuses on minimizing all possible emissions in place through modifying the manufacturing processes while the control focus on the technic to trap or destroy the pollutants. It is mentioned in article 24 of sub-degree on The Control of Air Pollution and Noise Disturbance about role and responsibility of the pollution source owners to control the pollution in place.

Table 4.3 Mitigation measures apply for industry sector

Mitigation Measures	Goals	Timeline
Sub-decree on The Control of Air Pollution and Noise Disturbance		
Implementing industrial emission control	50% reduction in industrial emission as a result of implementation of emission control *(Assumption)*	2030

Table 4.4 Emission reductions for industry mitigation measures by pollutant

Industry											
Branches	**Organic Carbon (MT)**	**Black Carbon (MT)**	**PM2.5 (MT)**	**PM10 (MT)**	**Ammonia (MT)**	**Sulfur-Dioxide (MT)**	**Nitrogen Oxide (MT)**	**Non-Methane Volatile Organic Compounds (Thousand MT)**	**Methane (MT)**	**Carbon Monoxide (Thousand MT)**	**Carbon Dioxide (Thousand MT)**
Baseline emissions (2030)	3,167.97	1,843.90	6,433.66	6,576.93	11.48	8,637.63	11,866.26	13.27	1,336.38	26.84	1,308.05
Implementation of all mitigation measures (2030)	1,547.59	900.75	3,142.95	3,212.93	12.22	8,438.96	5,806.40	12.97	1,305.64	26.22	1,277.96
Emission reduction (Baseline emissions - all mitigation measures)	1,620.38	943.15	3,290.71	3,364.00	-0.74	198.67	6,059.86	0.30	30.74	0.62	30.09
% Reduction	51.14	51.14	51.14	51.14	-6.45	2.30	51.07	2.26	2.30	2.31	2.30

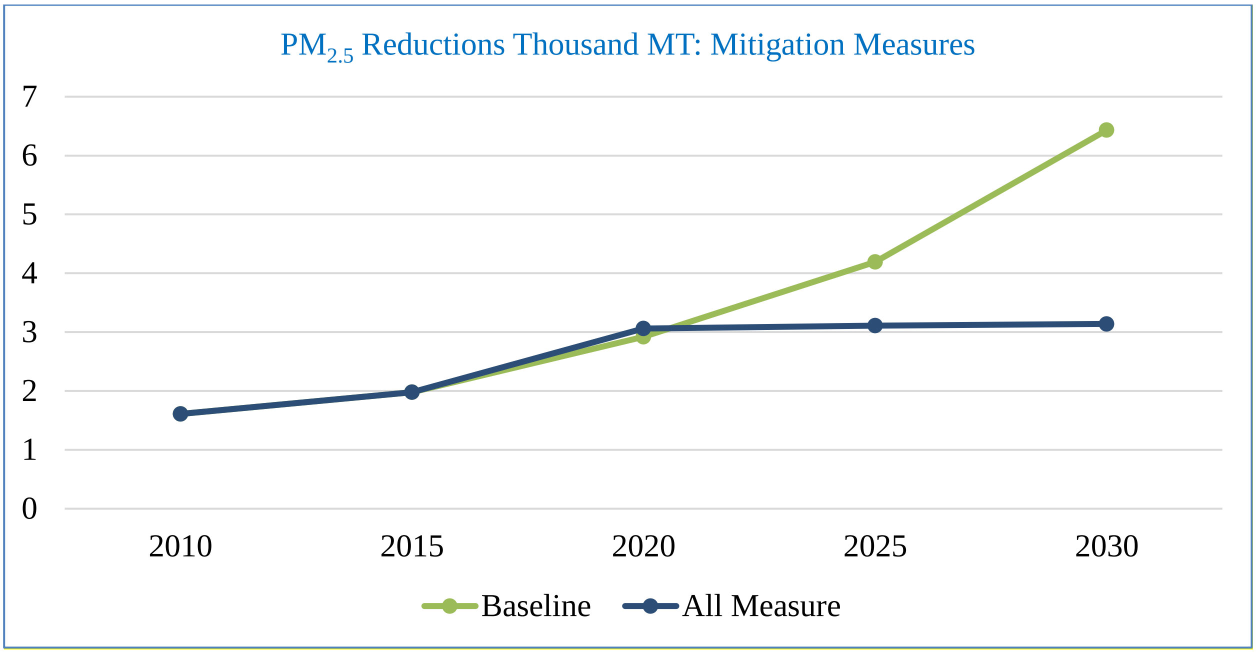

Figure 4.3 PM2.5 reductions from industry measures

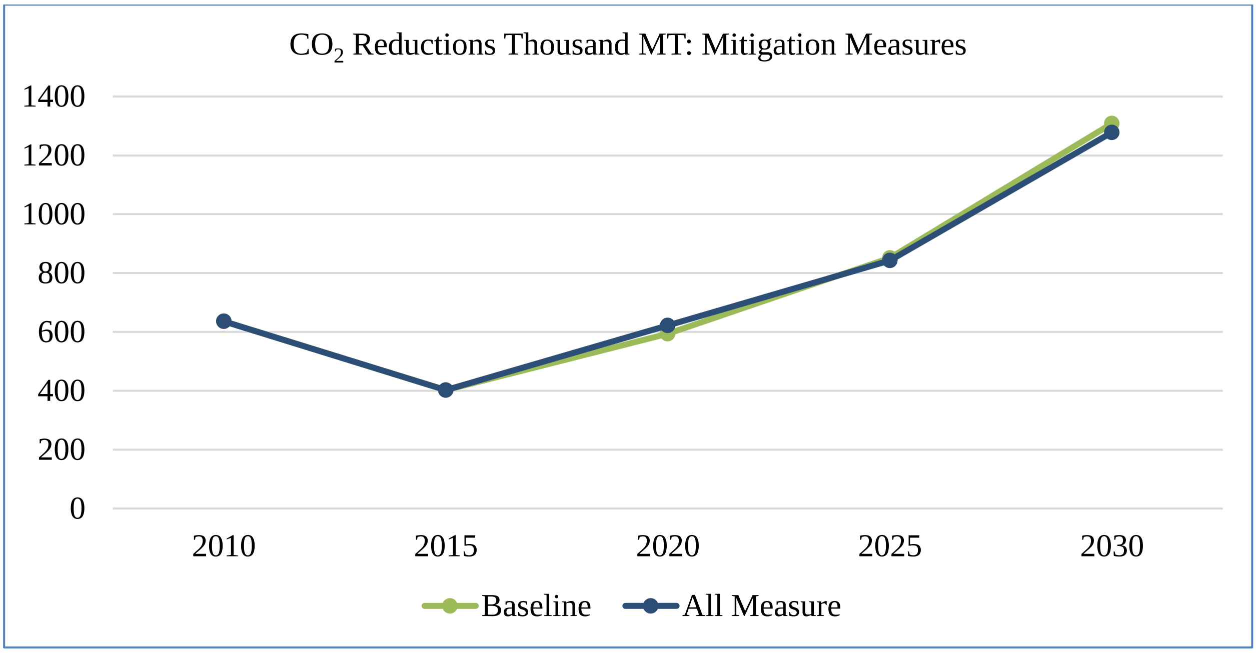

Figure 4.4 CO_2 reductions from industry measures

The implementation of the mitigation measures in industrial sector, in particular the implement of controlling pollution sources as stated in the sub decree on control of air pollution and noise disturbance could lead to significantly decrease of 51.15% of organic carbon, 51.14% of black carbon, 51.14% of PM2.5, 51.14% of PM_{10} and 51.07% of nitrogen oxide. As for PM2.5, slightly decrease is observed after 2020 and a significant decrease is expected by 2030.

4.3 Emission Control from Electricity Generation

The economic development and population growth affect on electricity consumption. The electricity generation increased almost 5 times between 2010 and 2015 and above 2 times higher in 2015 as compared to 2014 (of 2,981 GWh). For electricity generation, the energy for lighting, cooling and for equipment is the main source emitting air pollutants. In order to protect the human health and minimize the impact on the environment, emission control from residential sector is required. The mitigation measures focus on minimizing all possible emissions in place through improving energy efficiency.

Table 4.5 Mitigation measures apply for electricity generation

Mitigation Measures	Goals	Timeline
Cambodia's Updated Nationally Determined Contribution		
Energy Efficiency - Application of electrical equipment's labeling and Minimum Energy Performance Standards (lighting, cooling and equipment) - Improvement of process performance of energy efficiency by establishment of energy management in building/industries - Public awareness campaigns on energy saving - Building codes and enforcement/certification for new buildings and those undergoing major renovation - Introduction of efficient electrical motors and boilers	- Energy efficiency in residential sector improves by 31.7% - Energy efficiency in commercial and public services sector improves by 41.7% - Energy efficiency in industry sector improve by 2.3% *(Assumption)*	2030

Table 4.6 Emission reductions for electricity generation by pollutant

Electricity Generation											
Branches	**Organic Carbon (MT)**	**Black Carbon (MT)**	**PM2.5 (MT)**	**PM10 (MT)**	**Ammonia (MT)**	**Sulfur-Dioxide (Thousand MT)**	**Nitrogen Oxide (Thousand MT)**	**Non-Methane Volatile Organic Compounds (MT)**	**Methane (MT)**	**Carbon Monoxide (MT)**	**Carbon Dioxide (Thousand MT)**
Baseline emissions (2030)	20.74	16.29	412.14	853.05	19.67	44.65	21.94	135.31	106.59	846.76	8,698.47
Implementation of all mitigation measures (2030)	8.78	8.98	209.75	390.38	14.73	20.94	8.54	56.89	48.34	358.08	3,447.86
Emission reduction (Baseline emissions - all mitigation measures)	11.96	7.31	202.39	462.67	4.94	23.71	13.40	78.42	58.25	488.68	5,250.61
% Reduction	57.67	44.87	49.11	54.24	25.11	53.10	61.08	57.96	54.65	57.71	60.36

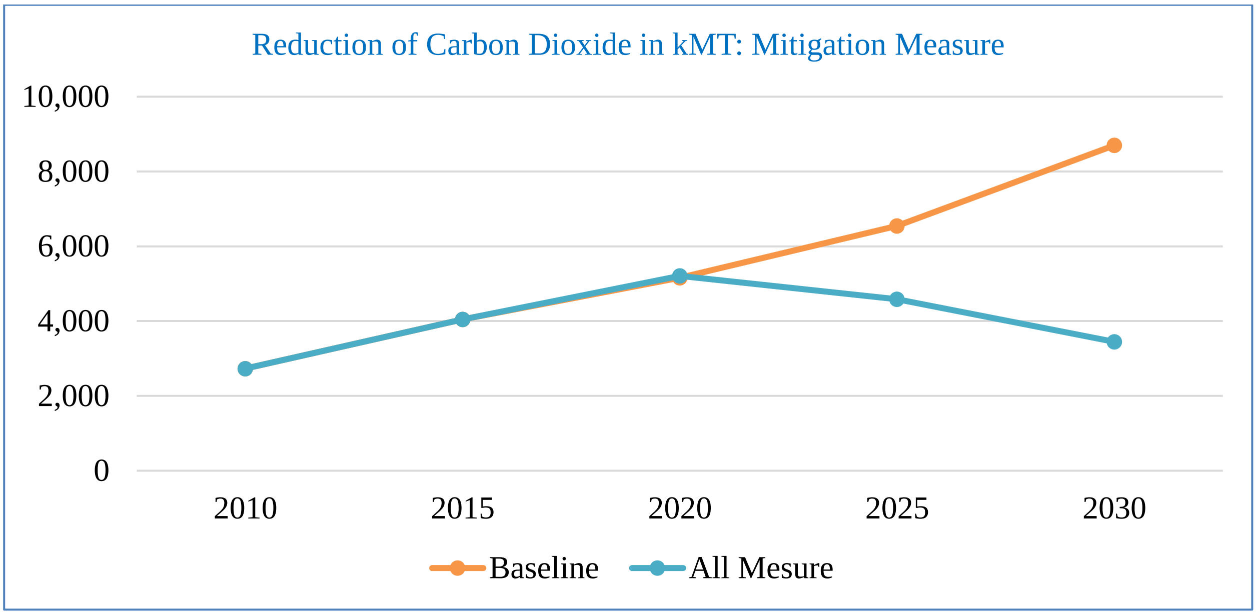

Figure 4.5 CO_2 reductions from electricity generation measures

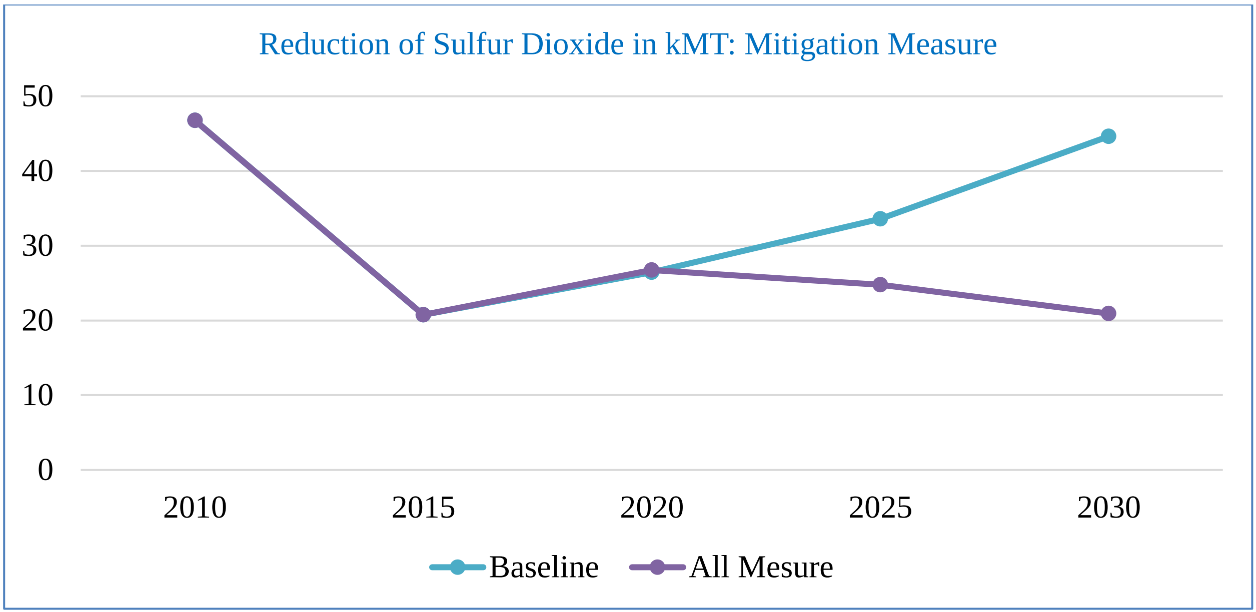

Figure 4.6 SO_2 reductions from electricity generation measures

The implementation of the mitigation measures in electricity generation, in particular the implement of improving energy efficiency as stated in the NDC could lead to significantly decrease of 57.67% of organic carbon, 44.87% of black carbon, 49.11% of PM2.5, 54.24% of PM_{10}, 61.08% of nitrogen oxide, 53.10% for sulfur dioxide and 60.36% for carbon dioxide.

4.4 Emission Control from Residential Sector

For residential sector, the energy for cooking and lighting is the main source emitting air pollutants. The consumption of the electricity as the lighting source at households was increased gradually from 75 ktoe in 2010 to 131 ktoe in 2015. For cooking, solid fuels (firewood and charcoal) remained shared the largest fuel mixed in Cambodia and followed by LPG. In order to protect the human health and minimize the impact on the environment, emission control from residential sector is required. The mitigation measures focus on minimizing all possible emissions in place through improving cooking stove and shifting from bio-mass to bio-gas.

Table 4.7 Mitigation measures apply for residential sector

Mitigation Measures	Goals	Timeline
Cambodia Climate Change Strategic Plan		
1- Promote and installing fuel efficiency stove in rural areas 2- Promote using bio-gas for cooking in rural areas	1- 60% of residential in rural switch from using less efficiency stoves 2- 60% of residential in rural switch from using bio-mass to bio-gas *(Assumption)*	1- 2030 2- 2030

Table 4.8 Emission reductions for residential mitigation measures by pollutant

Residential (Thousand MT)											
	Organic Carbon	Black Carbon	PM2.5	PM10	Ammonia	Sulfur-Dioxide	Nitrogen-Oxide	Non-Methane Volatile Organic Compounds	Methane	Carbon Monoxide	Carbon Dioxide
Baseline emissions 2030/Unit	13.89	4.19	32.00	39.86	4.34	3.96	10.83	128.78	24.19	406.34	24.20
Air Pollution Circular Measures 2030/Unit	4.24	1.42	9.84	12.16	1.43	1.30	3.59	39.60	7.97	149.54	69.14
Total Emission Reduction (Baseline Emission - All Measure)	9.65	2.77	22.16	27.70	2.90	2.67	7.24	89.17	16.22	256.80	-44.94
% Reduction	69.47	66.05	69.26	69.49	66.99	67.32	66.87	69.25	67.05	63.20	-185.71

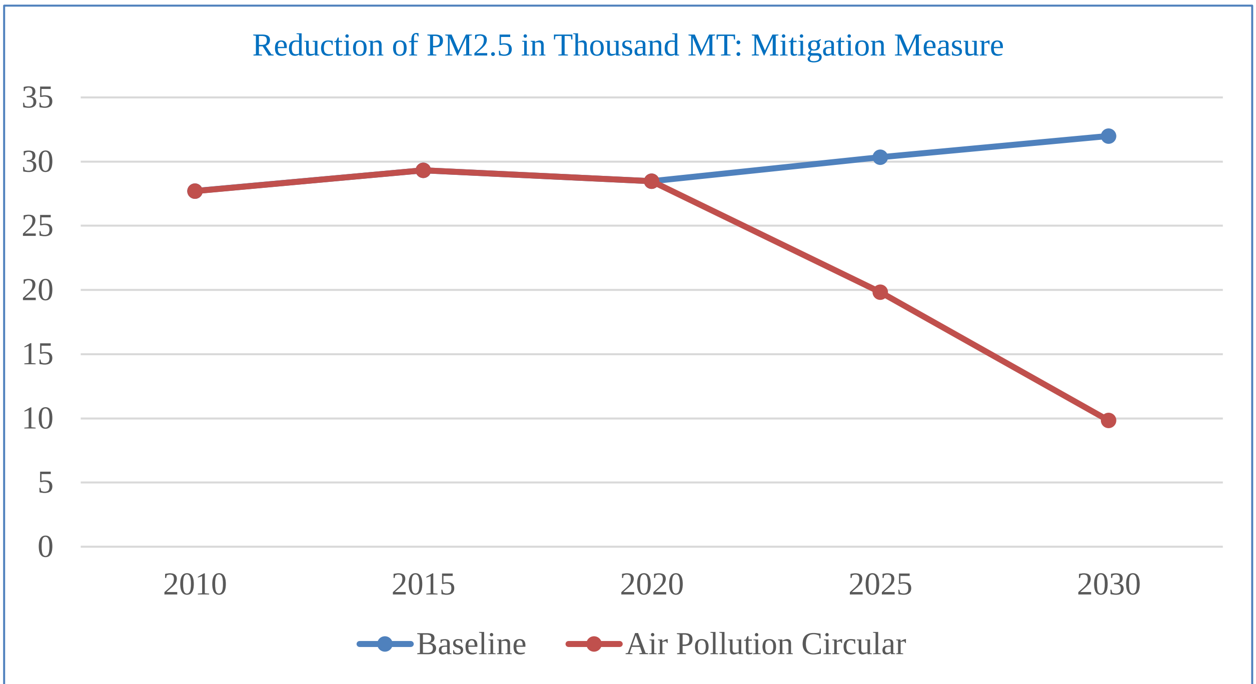

Figure 4.7 PM 2.5 reductions from residential measures

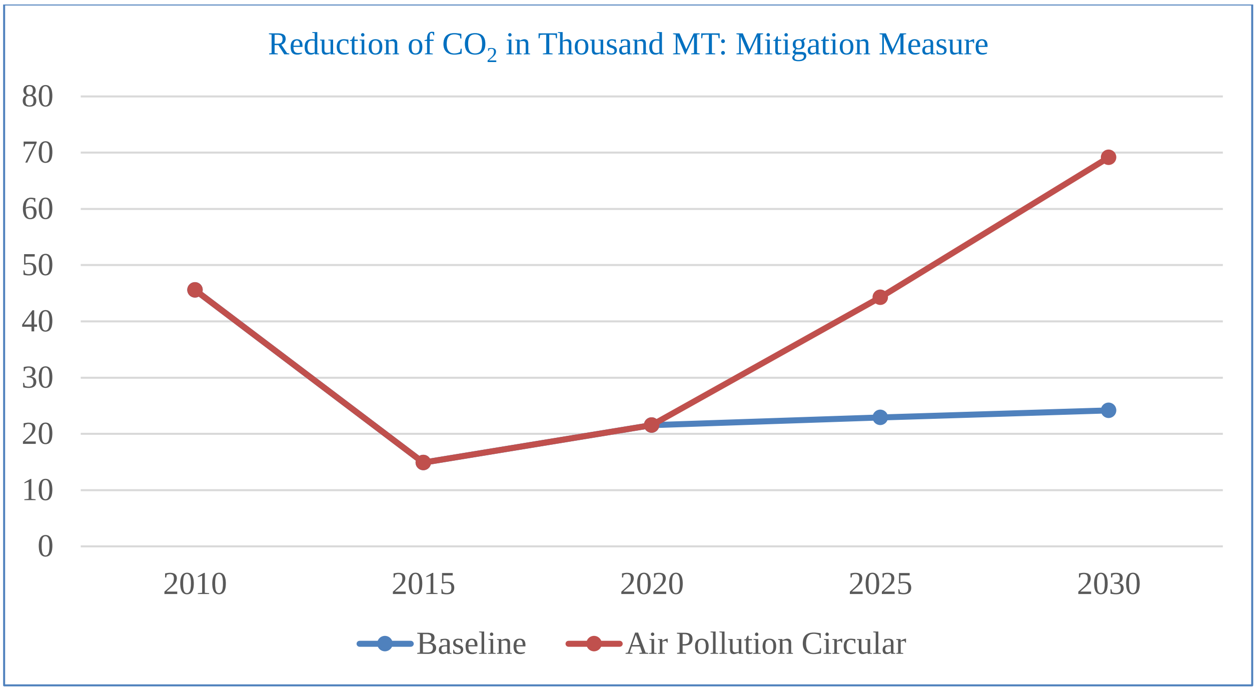

Figure 4.8 CO_2 reductions from residential measures

The implementation of the mitigation measures in residential sector, in particular the implement of controlling pollution sources as stated in the mitigation measures suggested by expert from Stockholm University could lead to significantly decrease of 69.47%% of organic carbon, 66.05% of black carbon, 69.26% of PM 2.5, 69.49% of PM_{10} and 63.20% of carbon monoxide. As for PM 2.5, slightly decrease is observed after 2020 and a significant decrease is expected by 2030.

4.5 Emission Control from other sources

In Cambodia, charcoal making was assumed still processed in traditional kilns with very low efficiency (11.43%) was used for transformation wood to charcoal. This traditional method of charcoal making shows the largest pollution was carbon monoxides. There is currently no regulation in place to address emissions from charcoal making. In order to alleviate the air pollution emission from this source for public health and environmental sake, improving efficiency of charcoal production through enhancing charcoal kiln efficiency is required.

Table 4.9 Mitigation measures apply for charcoal making source

Mitigation Measures	Goals	Timeline
Additional recommended measure: Charcoal Making		
Improve efficiency of charcoal production	Charcoal kiln efficiency increase from 11% to best available 30% efficiency *(Assumption)*	2030

Table 4.10 Emission reductions for charcoal making mitigation measures by pollutant

Charcoal Making									
	Organic Carbon (MT)	**Black Carbon (MT)**	**PM2.5 (MT)**	**PM10 (MT)**	**Ammonia (MT)**	**Sulfur-Dioxide (MT)**	**Non-Methane Volatile Organic Compounds (MT)**	**Methane (MT)**	**Carbon Monoxide (MT)**
Baseline emissions 2030/Unit	4,589	676	9,248	9,248	1,316	2,047	116,670	47,664	344,318
All Measures 2030/Unit	1,748	257	3,524	3,524	501	780	44,451	18,160	131,185
Total Emission Reduction (Baseline Emission - All Measure)	2,841	419	5,724	5,724	815	1,267	72,219	29,504	213,133
% Reduction	61.91	61.98	61.89	61.89	61.93	61.90	61.90	61.90	61.90

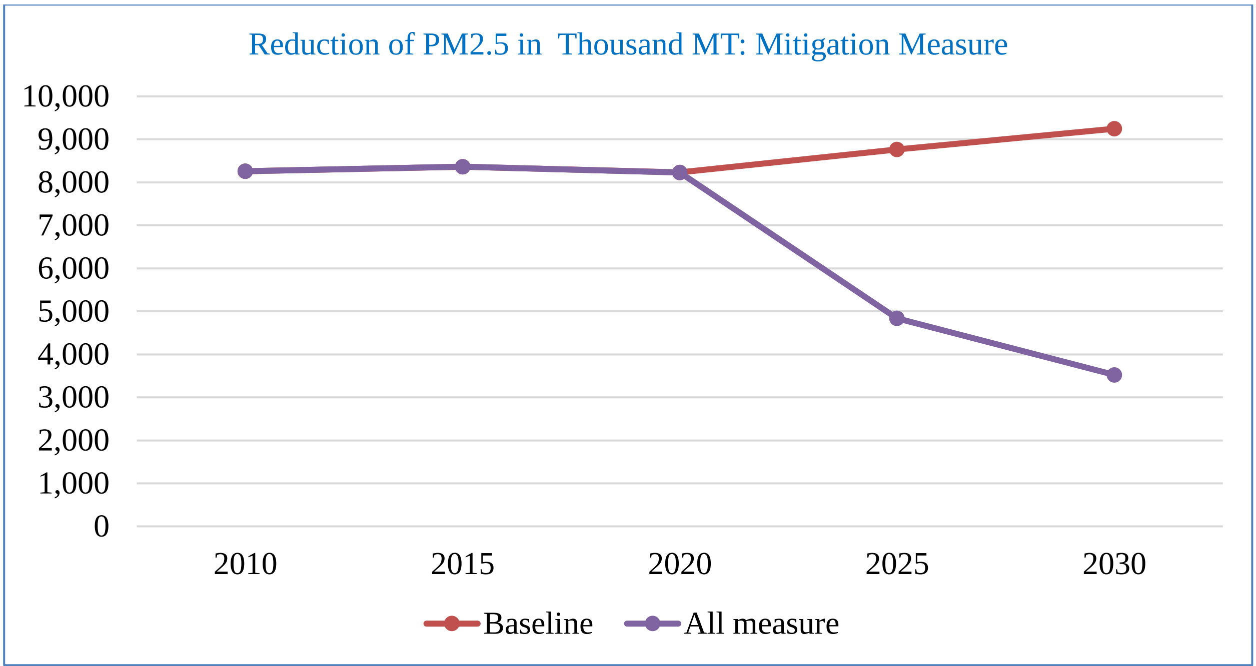

Figure 4.9 PM 2.5 reductions from charcoal marking measures

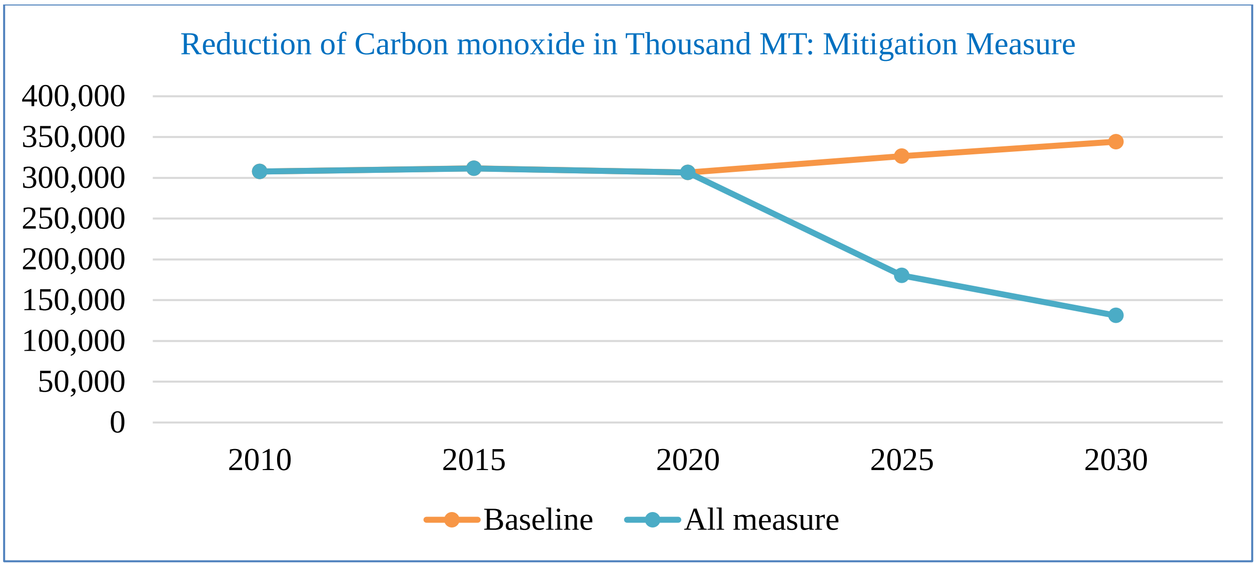

Figure 4.10 CO reductions from charcoal making measures

The implementation of the mitigation measures in charcoal making, in particular the implement of controlling pollution sources as stated in the mitigation measures suggested by expert from Stockholm University could lead to significantly decrease of 61.91% of organic carbon, 61.98% of black carbon, 61.89% of PM 2.5,61.93 of ammonia, and 61.90% of sulfur dioxide, NMVOC, methane and carbon monoxides.

4.5.1 Emission Control from Construction Sites

Within the processes, include earthmovings, tunnel and bridge works, transportation of materials, concrete production, and operation of machines and equipment generate wastes and pollution. Minimizing the impacts to the environmental is a challenging task to achieve. Among those impacts, emissions of particulate matter, such as particulate matter with a particle size that is less than ten microns in size (PM_{10}), and gases released by the machineries and equipment used during construction play a significant role to lower air quality. Even though the emissions are temporary, significant impact is still there and thus, properly measure and mitigation are needed. There shall be a reinforcement on the management of dust or particulate matter into the air and other discharges from pollutant sources, such as construction sites, concrete production sites, transport of pebble sand, cement or other construction materials by means to require prior tire cleaning from the production sites, installation of high pressure steam spray, and apply the proper tire cover before leaving out from the business sites in order to avoid any spills or crumbs and dusty or particulate matter in to the roads. On the other hand, there shall be a reinforcement on the inspection and strengthening the education to all construction site owners.

Table 4.11 Mitigation measures apply for construction sector

Mitigation Measures	Goals	Timeline
Circular N. 01 on Measures to Prevent and Reduce the Ambient Air Pollution		
Administration of Construction Site 1- Shall be reinforced the management of dust or particulate matter into the air and other transport of pebble sand, cement or other construction materials by means to require prior tier cleaning from the production sites, installation of high-pressure steam spray, and apply the proper tire cover before leaving out from the business sites in order to avoid any spill or crumbs and dusty or particulate matter in to the roads. 2- Shall be reinforce the inspection and shall be strengthened the education to all construction site owners	50% of all construction projects implement air pollution reduction measurement on administration of construction sites *(Assumption)*	2030

Table 4.12 Emission reductions for construction mitigation measures by pollutant

Construction											
Branches	**Organic Carbon (MT)**	**Black Carbon (MT)**	**PM2.5 (MT)**	**PM10 (MT)**	**Ammonia (MT)**	**Sulfur-Dioxide (MT)**	**Nitrogen Oxide (MT)**	**Non-Methane Volatile Organic Compounds (MT)**	**Methane (MT)**	**Carbon Monoxide (MT)**	**Carbon Dioxide (TMT)**
Baseline emissions (2030)	-	-	2,222	22,225	-	-	-	-	-	-	-
Air circular measures (2030)	-	-	1,667	16,669	-	-	-	-	-	-	-
Emission reduction (Baseline emissions - all mitigation measures)	-	-	555	5,556	-	-	-	-	-	-	-
% Reduction	-	-	25	25	-	-	-	-	-	-	-

In Cambodia, residential construction has mainly contributed to the emission from construction. In 2020, the residential construction activities alone produced up to 48.59 % of particulate matter from construction site sector. With implementation of mitigation measures 25% of PM_{10} and 25 % of PM2.5 is expected to be reduced in construction sector by 2030.

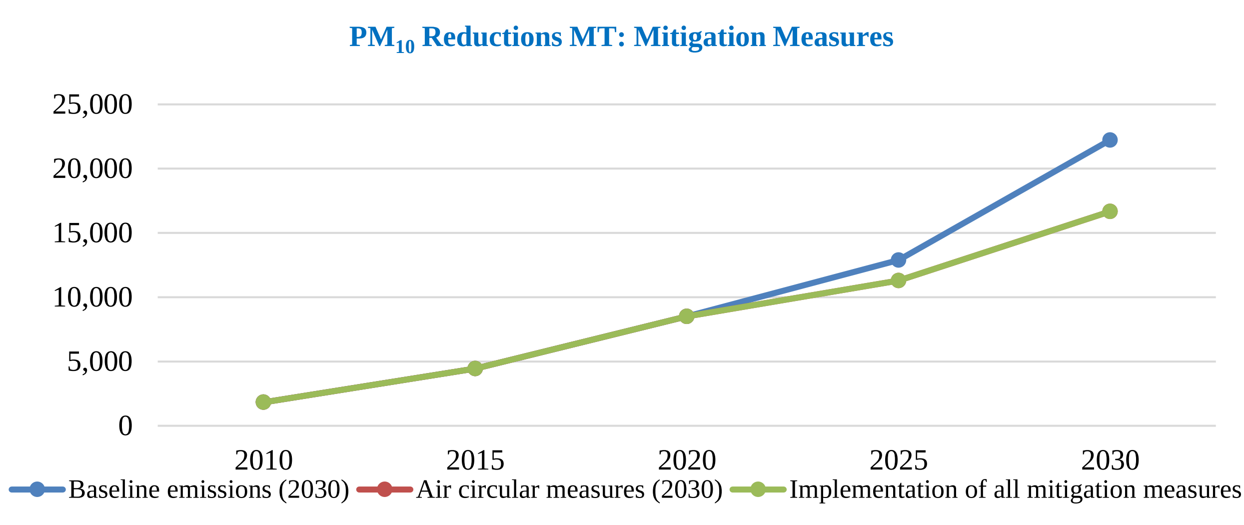

Figure 4.11 PM10 reductions from construction measures

4.5.2 Emission Control from Open Waste Burning

Emissions from open burning are typically affected by many variables including wind, ambient temperature, moisture content of the debris burned, composition and compactness of the pile. Generally, the relatively low temperatures burning, for instance open burning, increase emissions of particulate matter, carbon monoxide, and hydrocarbons and suppress emissions of nitrogen oxides. The open burning can be categorized as open burning of biomass fuel (agricultural residue wastes, forest fire, etc.) and solid anthrophonic fuel open burning (for example, household solid waste). The open burning, which is not an ideal combustion, generally produces soot and particulate matter (PM), carbon monoxide (CO), methane (CH_4) and other light hydrocarbons etc. that can be found in form of smoke plume. Open burning emissions are troubling from a public health perspective because during open burning, the emissions are not released through tall stacks which aid dispersion, but it stays at or near the ground level. It is not spread evenly throughout the year but they are typically episodic in time or season and also localized/regionalized.

Table 4.13 Mitigation measures apply for open waste burning

Mitigation Measures	Goals	Timeline
Circular N. 01 on Measures to Prevent and Reduce the Ambient Air Pollution		
The administration of the opened-field waste burning 1- Must have strategies to prevent and to avoid of all kinds of forest cleaning, burning of garbage, burning solid waste in the open areas, landfill and public squares 2- Must educating people to stop burning garbage, solid waste, grasses, stalks and other agricultural wastes 3- If having severe forest fire, must immediately apply strategies through using all possible means in order to effectively extinguish the forest fire	1- 50% reduction of illegal opened waste burning across country through implementing air pollution reduction measurement on administration of air pollutants emission from opened-field waste burning *(Assumption)*	1- 2030

Table 4.14 Emission reductions for open waste burning mitigation measures by pollutant

Waste (Thousand MT)											
Branches	**Organic Carbon**	**Black Carbon**	**PM2.5**	**PM10**	**Ammonia**	**Sulfur-Dioxide**	**Nitrogen-Oxide**	**Non-Methane Volatile Organic Compounds**	**Methane**	**Carbon Monoxide**	**Carbon Dioxide (MT)**
Baseline emissions (2030)	11.98	1.49	22.29	27.06	2.55	1.14	11.15	51.38	8.32	86.4	-
Air circular measures (2030)	5.99	0.75	11.15	13.53	1.28	0.57	5.58	25.69	4.16	43.2	-
Emission reduction (Baseline emissions - all mitigation measure)	5.99	0.74	11.14	13.53	1.27	0.57	5.57	25.69	4.16	43.2	-
% Reduction	50	49.66	49.98	50	49.80	50	49.96	50	50	50	-

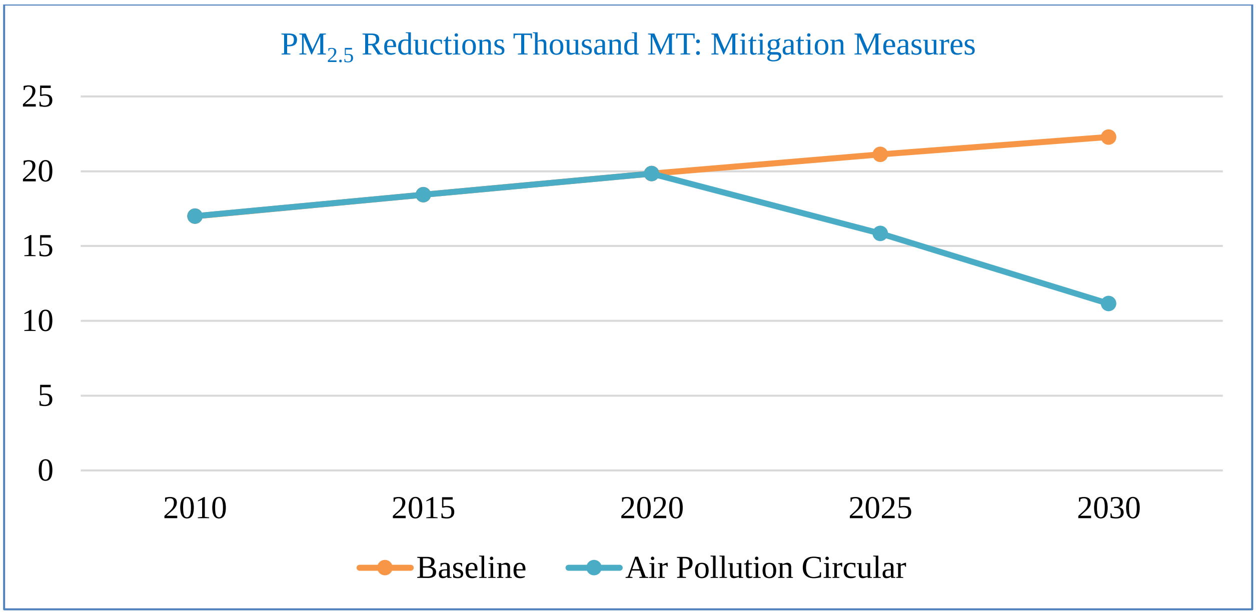

Figure 4.12 PM2.5 reductions from open waste burning mitigation measures

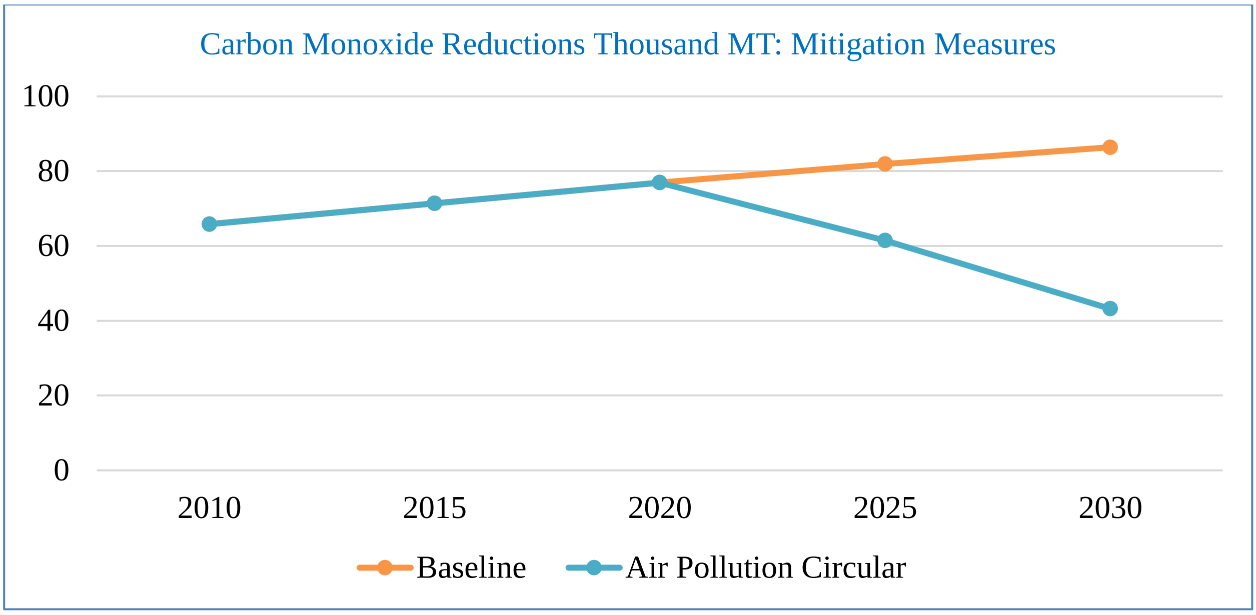

Figure 4.13 CO reduction from open waste burning mitigation measures

Through the implementation of the mitigation measures in the waste sector, the emissions reduction from waste sector by 2030 will be 50% for Methane, 50% for Carbon Monoxide, 50% for PM_{10} and 49.98 % for PM 2.5. There reduction in of pollutants is observed after in 2020 due to the implementation of a measure that would stop burning of municipal waste. This is will be an effective measure which provide immediate results in reducing emissions in this sector.

Solid waste management strategy will be a solution. According to Sub-decree on Urban Garbage and Solid Waste Management, which is establish in August 2015 with the goal to enhance the management of garbage and solid waste of urban areas with effectiveness, transparency and accountability, referring to ensure aesthetics, public health and environmental protection the management centralization. In mid-February 2021 the Urban Garbage and Solid Waste Management Committee was established to fulfill the objective that the solid waste is properly managed from the places of generation until waste processing in order to turn the waste into electricity.

5. IMPLEMENTATION AND MONITORING THE MEASURES

5.1 Characterizing the nature of the air pollution problem

Appropriate ambient air quality monitoring is required to tell the nature of the air pollution using air quality index and make good quality data available to the public. With real-time ambient air quality monitoring, the information on pollution compositions, concentration, and source sector will be known. The data from the monitoring are of important to map the trends and seasonal variations in air quality, to alert to public to take action on days with high levels of pollution, and to evaluate the effectiveness of the implementation of mitigation measures.

5.2 Developing an emission inventory

Air pollutant emission inventory, an indispensable tool for a wide range of environmental measures, is a scientific tool available for the management of the atmospheric environment. With the inventory, the types of activities that cause emissions, the chemical or physical identity of the pollutants are included and quantified. Therefore, the geographic area covered, the time period over which emissions are estimated and the methodology used are determined. The inventory, which is developed within the national planning process, is of critical important in the process of monitoring, evaluating, reviewing and updating the air quality plan. The inventory development process will be updated every 5 years to allow the implementation of the plan to be tracked.

5.3 Identifying the air quality goal and timeframe for achievement

It is essential to establish specific air quality goals. The emission inventory is an important baseline information for estimating future emissions by projection based on the changes in socio-economic indices (e.g. economic growth, population growth, changes in energy use…), emission factors (e.g. after the introduction of better control measures), fuel substitution and so on. The estimation of future emissions provides important information for setting emissions targets and time needed to achieve the target, for example, a reduction of 35 % of PM 2.5 by 2030 in Phnom Penh.

5.4 Conducting air quality modelling and identifying new emission reduction strategies in order to achieve the air quality goal

Existing technology is accessed to improve and maintain air pollution, GHG emission inventory and projections. Data on emissions play a role as the input for atmospheric transport and deposition models. The concentration and deposition can be estimated by modeling, in comparison with the monitoring data on the ground and/or from satellite, will be of important information for decision-making regarding to air quality management. The air quality modelling, like the mentioned in this document, will enable to understand how the implementation of programs will contribute to achieving the air quality goal.

5.5 Formulating and adopting the requirements

Other than to setting an emission standard, regulations should reflect the country's context after have been oversaw from different point of view, best match to available technology, and needs to include source monitoring and reporting requirements. Proposed regulations should undergo a reasonable commenting period with approval from relevant stakeholders.

5.6 Implementing effective programs for permitting and enforcement

Permit is an effective tool to ensure that the emission source owner have enough knowledge and understanding regarding to air pollution control requirements they have to fulfill. For example, renewing permits for vehicles that comply with the national vehicle emission standards, the renewing of air emission from manufacturing, the implementation of monitoring plan or spot check the see if the pollution source owners have really complied with the existing frameworks they are supposed to fulfill.

5.7 Monitor implementation of air pollution mitigation measures identified in this plan

An emission inventory provides the baseline information that enables the likely effects of introducing of various prevention and control measures with several sectors to be assessed and compared between now and what it supposes to be in the future. Based on knowledge on costs of each option, decision-maker will be able to select the most the effective and efficiency emission reduction measures. The emission inventory data play a role as an index which share some similarities to those used in economic trend. The trend allows us to judge whether we should introduce or reinforce regulations, economic measures or technical measures to control air pollutant emissions.

5.8 Public participation

Improving the effectiveness of environmental decision making requires sustained participation by relevant stakeholders. Participation from people of all group, especially the disadvantaged, can influence policy formulation, design alternatives, investment choices, and management decisions. Three groups that should participate in planning and management are 1.) those whose interests are affected by environmental problems, strategies, and plans; 2.) those who control relevant implementation instruments; and 3.) those who possess relevant information and expertise.

5.9 Review and update Air Pollution Action Plan

Review and update Air Pollution Action Plan every 5 years to ensure that all relevant corporate strategies and policies and the implemented mitigation measures reflect the importance of improving local air quality and reducing exposure in the country.

Table 5.1 Air Pollution Action Plan Roadmap: Activities, Organizations and time line

Activity	Sub-actions	Organizations Involved	Time Frame
Conduct appropriate ambient air quality monitoring to see the nature of the air pollution and make good quality data available to the public.	• Establish monitoring station(s) in key areas • Map trends and seasonal varieties in ambient air quality • Produce daily air quality data and make it accessible to the public	• Ministry of Environment	Ongoing
Access to existing technology to improve and maintain air pollution and GHG emission inventory and projections	• Continue developing existing LEAP-IBC analysis in Cambodia • Conduct studies on air pollution emission from factors • Cooperate with academic institutions	• Ministry of Environment • Academic institutions	2021-2030
Set ambient air pollution concentration goal and timeline for achievement	• Establish appropriate mitigation measures for each sector (transport, industry, agriculture…) • Implementation of the mitigation measures • Revising or developing regulations related Air pollution control.	• Ministry of Environment • Ministry of Public Work and Transport • Ministry of Industry, Science, Technology and Innovation • Ministry of Planning • Ministry of Mine and Energy • Ministry of Agriculture Forestry and Fishery • Ministry of Land Management, Urban Planning and Construction	2022-2030
Continue to trial low and zero emission technology	• Take all opportunities to trial and evaluate new low and zero emission • Promote new low and zero emission among sectors	• Ministry of Environment • Ministry of Industry, Science, Technology and Innovation • Ministry of Agriculture Forestry and Fishery • Academic institutions/environmental companies	Ongoing

Increase awareness of air pollution amongst public	• Conduct events with an information stall. Provide information for newsletters. • Encourage public to take part in • reducing air pollution • Widely disseminates to public the knowledge of air pollution and controls (social media, education curriculum…)	• Ministry of Environment • Ministry of Education, Youth and Sport • Sub – national level	Ongoing
Mainstream air pollutants and SLCPs into MRV and implementation	• Monitor implementation of measures and quantify their air pollutant emission reductions	• Ministry of Environment	2022 - 2030
Coordinate implementation of air pollution mitigation measures	• Formulating and adopting enforceable national requirements on emission limits and standards • Implement effective programs for permitting and enforcement	• Ministry of Environment	2022-2030
Monitoring and Evaluation of Clean Air Plan	• MRV framework for sustainable low emissions transport • Monitor implementation of mitigation measures identified in Plan • Review and update National Air Pollution Action Plan accordingly	• Ministry of Environment	2022 - 2030

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APPENDIX

ANNEX 1

The technical working group has duty to perform the task as follow:

1. Participating in activities that are essential to run the project implementation smoothly
2. Establishing an inter-ministerial SLCP working group including terms of reference of the working group and operational modality
3. Establishing communication network and information sharing mechanisms including development of national knowledge exchange network platform on CCAC/SLCPs
4. Conducting consultation workshops, awareness workshop and public campaigns on SLCPs for the stakeholders
5. Develop training materials, leaflet, and brochure on SLCPs and its implications, benefits of reductions
6. Developing national framework and guideline/guidance on CCAC initiatives, SLCPs mitigation strategy and action plans
7. Conducting an assessment on status of knowledge and level of recognition of stakeholders on SLCPs
8. Identify potential sectors and list of actions to reduce short-lived climate pollutants
9. Participating in LEAP IBC training and developing a national black carbon inventory covering key sectors
10. Mainstreaming CCAC initiatives including SLCPs mitigation strategy and plans into sectoral/ national strategy and action plans of government institution/ ministries.

ANNEX 2: Data Collection from each sector

Source Sector	Methodology	Sub-sectors	Activity Data	Emission Factors
Residential	Emissions = Activity * Emission Factor Activity = Fuel Consumption Fuel Consumption = Households * Energy Intensity	Split by activity and technology, e.g. Cooking Lighting Appliances Cooling Heating Other etc.	Default: Total energy consumption by activity, technology and fuel Alternative: Proportion of households that do each activity, with each fuel or technology (e.g. number of households that cook using solid biomass, number of households with air conditioning) Energy intensity of individual activities, fuels and technologies (e.g. energy consumption of an air conditioner, energy consumption of biomass stove)	Pollutants: CO2, CO, CH4, NMVOCs, N2O, NOx, SO2, PM10, PM2.5, BC, OC, NH3 Units: kg per unit energy consumed
Commercial and Public Services	Emissions = Activity * Emission Factor Activity = Fuel Consumption Fuel Consumption = Value Added * Energy Intensity	Default: None Alternative: Disaggregated to individual commercial (e.g. restaurants, hotels, shops etc.) and public (e.g. hospitals, government buildings etc.) services Disaggregation could also include activities and technologies within commercial and public services (e.g. lighting, heating, cooking, cooling etc.) to	Default: Total energy consumption by fuel Alternatives: Total energy consumption for sub-sectors by activity, technology and fuels Data on the number of commercial and public services that do each activity with each technology, and energy intensity of each activity/technology	Pollutants: CO_2, CO, CH_4, NMVOCs, N2O, NOx, SO_2, PM10, PM2.5, BC, OC, NH3 Units: kg per unit energy consumed

		understand activities contributing to energy consumption and emissions	(e.g. number of hotels with air conditioning, and average energy consumption of air conditioners in hotels)	
Transport	Emissions = Activity * Emission Factor Non-road vehicles Activity = Annual fuel consumption (TOE)	Road Rail Aviation Domestic Shipping Pipelines Other	Default: Total energy consumption in each transport sub-sector, split by fuel Alternatives: Road: Number of vehicles in fleet split by vehicle type, fuel used, vehicle emission standards. Average distance travelled by vehicles of each type per year Average fuel consumption of vehicle in each category Aviation Number of domestic and international flights per year Total fuel used (or fuel sold) for domestic and international flights.	Pollutants: CO_2, CO, CH_4, NMVOCs, N2O, NOx, SO_2, PM10, PM2.5, BC, OC, NH3 Units: kg per unit energy consumed Alternatives: For air pollutants (i.e. not CO_2, CH_4) kg per km travelled for alternative transport method
Industry	Emissions = Activity * Emission Factor Activity = Fuel Consumption Fuel Consumption	Default: Brick Kilns reported separately to all other industry Alternative: Disaggregated to individual industrial sub-sectors (e.g. chemical, paper, iron and steel etc.	Default: Total energy consumption by fuel for all industries except brick kilns Brick Kilns: Total number of bricks produced per year	Pollutants: CO2, CO, CH4, NMVOCs, N2O, NOx, SO2, PM10, PM2.5, BC, OC, NH3

	= Production * Energy Intensity * Fuel Share	Disaggregation could also include activities and technologies within industries	by traditional and improved brick kilns Alternatives: Total energy consumption for sub-sectors by activity, technology and fuels Data on the number of industries that do each activity with each technology, and energy intensity of each activity/technology	Units: kg per unit energy consumed
Agriculture, Forestry and Fishing	Emissions = Activity * Emission Factor Activity = Fuel Consumption Fuel Consumption = Value Added ($) * Energy Intensity	Default: None Alternative: Disaggregated to individual agricultural, forestry and fishing sub-sectors and/or activities (e.g. agricultural machinery, fishing boats etc.)	Default: Total energy consumption by fuel for all agriculture, forestry and fishing sector Alternatives: Total energy consumption for sub-sectors by activity, technology and fuels Data on the number of, e.g. agricultural machinery or fishing boat trips per year split by with each technology, and energy intensity of each activity/technology	Pollutants: CO_2, CO, CH_4, NMVOCs, N_2O, NO_x, SO_2, PM_{10}, $PM_{2.5}$, BC, OC, NH_3 Units: kg per unit energy consumed
Energy Industry Own Use		Default: Split by Petroleum Refining and Other Own Use	Default: Total energy consumption by fuel for Petroleum Refining and Other Own Use	Pollutants: CO_2, CO, CH_4, NMVOCs, N_2O, NO_x, SO_2, PM_{10}, $PM_{2.5}$, BC, OC, NH_3

				Units: kg per unit energy consumed
Transmission and Distribution of Electricity			Losses in transmission and distribution of electricity (%)	N/A
Electricity Generation		Default: Split by fuel/technology used to generate electricity	Default: Percent share of electricity generated for each fuel. Efficiency of electricity generation for each process Alternatives: Capacity (MWh) of each fuel for generating electricity System load curve for electricity generation	Pollutants: CO_2, CO, CH_4, NMVOCs, N_2O, NOx, SO_2, PM10, PM2.5, BC, OC, NH_3 Units: kg per unit energy consumed
Oil Refining		None	Imports and exports of oil products (gasoline, diesel, kerosene, heavy fuel oil, LPG, Other)	kg per unit energy consumed
Oil Production		None	Imports and exports of crude oil	kg per unit energy consumed
Natural Gas Production, Processing and Distribution		None	Imports and exports of natural gas	kg per unit energy consumed
Charcoal Making		Traditional and improved charcoal kilns	Imports and exports of charcoal % charcoal produced using traditional and improved kilns	kg per unit energy consumed
Coal Mining		Surface and Underground mining	Imports and exports of coal % coal mined from surface and underground mining	kg per unit energy consumed
Coke Production		Traditional and Improved ovens	Imports and exports of coke	kg per unit energy consumed

			% coke produced in traditional and improved mines	
Oil Exploration			Number of wells drilled	Kg per well drilled
Gas Flaring from oil production			Volume of gas flared	Kg per m3 gas flared
Industrial Process Emissions		Minerals Chemicals Metals Pulp and Paper Alcoholic Beverages Food Production Building Construction	Total annual production of each mineral, chemical, metal etc. Building construction rate (Hectare-months per year)	Kg per tonne product produced
Solvent Use		Paint Application Metal Degreasing Dry Cleaning Chemicals Manufacture Other Use of Solvents	Total annual production and/or use of each solvent in each activity	Kg pollutant per tonne product sold/used
Agriculture	Emissions = Activity * Emission Factor Activity = Fuel Consumption Fuel Consumption = Value Added ($) * Energy Intensity	Livestock Enteric Fermentation and Manure Management Particulates from Animal Housing Fertiliser Application Agricultural Residue Burning Methane from Rice Cultivation	Number of animals of each type % time animals spend in housing Tonnes of fertiliser applied to fields Annual crop production, percentage of crop residue burned in field Hectares of land used for rice production that are managed as continuously flooded fields, that are intermittently aerated or that are rainfed or deepwater	Kg per animal Kg per animal Kg per kg N fertiliser applied Kg per tonne crop residue burned

Waste		Methane from municipal solid waste in landfill	Population whose waste is collected Annual waste generation rate (kg/person/year) Fraction of waste collected disposed in landfill Fraction of waste that is organic	
		Waste Incineration	Tonnes of waste that is openly burned or burned in waste incinerators	Kg per tonne waste burned
		Ammonia from human excreta Methane from domestic water	Total Population who have latrines vs outside Fraction of population with different waste water treatment types (Latrines, Septic Tank, Anaerobic reactor or deep lagoon, aerobic treatment plant, untreated discharge)	Kg per person per year
Vegetation Fires		Split by land cover type: Savannah Primary Tropical or Subtropical forest Secondary Tropical or Subtropical forest Pasture Other forest Shrubland Grasslands Peatland Other	Annual area burned for each landcover type	Kg per tonne biomass burned
HFCs		Emissive applications (aerosol solvents, propellants, other)	HFC sold in each year for each application	

		Contained application (foam blowing agents, fire protection, refrigeration and air conditioning, other)	HFC imported or manufactured for each application	

ANNEX 3: Environmental Effects (Emissions) with all scenario by 2030 (Thousand MT)

Scenario	Organic Carbon	Black Carbon	PM2.5	Ammonia	Sulfur Dioxide	PM10	Nitrogen Oxides	Non Methane Volatile Organic Compounds	Methane	Carbon Monoxide	Carbon Dioxide
2015	31.8	8.5	68.1	124.9	32.9	83.9	127.0	462.2	304.4	1,234.2	13,608.1
Baseline 2030	45.0	14.6	98.5	112.0	70.0	132.4	329.0	1,119.2	218.2	2,725.6	40,150.8
Construction Controls	45.0	14.6	97.9	112.0	70.0	126.9	329.0	1,119.2	218.2	2,725.6	40,150.8
Euro 4 Buses	45.0	14.0	97.4	112.0	70.0	131.3	314.8	1,116.7	218.2	2,718.6	39,884.1
Euro 4 Freight	44.7	12.6	94.5	112.0	69.7	128.4	249.2	1,109.4	218.2	2,699.4	39,047.6
Euro 4 cars	44.8	14.4	98.1	112.4	69.9	132.0	306.5	1,092.9	218.0	2,521.4	39,715.1
Euro III Motorcycles	37.8	12.9	87.4	112.0	70.0	121.3	319.2	457.6	215.6	1,637.1	39,983.3
Improved Charcoal	42.1	14.2	92.8	111.2	68.8	126.7	328.6	1,047.0	188.7	2,512.5	40,150.8
Industrial Emission Controls	43.4	13.6	95.3	112.0	70.0	129.1	323.0	1,119.2	218.2	2,725.6	40,150.8
More efficient biomass stoves	45.0	14.6	98.5	112.0	70.0	132.4	329.0	1,119.2	218.2	2,725.6	40,150.8
NDC Energy Efficiency	44.9	14.5	98.3	112.0	59.5	132.1	323.6	1,118.9	218.2	2,724.8	38,110.4
NDC Renewable Electricity Generation	45.0	14.6	98.4	112.0	52.4	132.1	318.0	1,119.1	218.2	2,725.2	35,900.6
Open Waste Burning	39.0	13.8	87.4	110.7	69.5	118.9	323.4	1,093.5	214.1	2,682.4	40,150.8
Sulphur Fuel Quality	45.0	14.6	98.5	112.0	62.2	132.4	329.0	1,119.2	218.2	2,725.6	40,150.8
Switch biomass to gas stoves	35.3	11.8	76.3	109.1	67.4	104.7	321.7	1,030.0	202.0	2,468.8	40,195.8
Switch to public transport	45.0	14.6	98.6	112.0	70.0	132.5	329.1	1,116.1	218.1	2,699.5	39,935.0
Tour bus standards	45.0	14.6	98.5	112.0	70.0	132.4	329.0	1,119.2	218.2	2,725.6	40,150.8
Air Pollution Circular	22.0	9.3	53.2	108.1	59.0	74.2	286.4	315.9	195.0	1,127.2	39,420.3
All Measures	17.2	5.3	38.7	107.3	33.5	59.4	171.0	230.7	165.3	879.0	32,689.1

ANNEX 4: Environmental Effects (Percentage Reduction in Emissions) for individual mitigation actions in 2030 compared to the baseline scenario

Scenario	Organic Carbon	Black Carbon	PM2.5	Ammonia	Sulfur Dioxide	PM10	Nitrogen Oxides	Non Methane Volatile Organic Compounds	Methane	Carbon Monoxide	Carbon Dioxide
2015											
Baseline 2030											
Construction Controls	-	-	0.6	-	-	4.2	-	-	-	-	-
Euro 4 Buses	-0.0	3.7	1.1	-	0.1	0.8	4.3	0.2	0.0	0.3	0.7
Euro 4 Freight	0.7	13.5	4.1	-	0.5	3.1	24.3	0.9	0.0	1.0	2.7
Euro 4 cars	0.4	1.4	0.4	-0.3	0.2	0.3	6.8	2.4	0.1	7.5	1.1
Euro III Motorcycles	16.0	11.3	11.3	0.0	0.1	8.4	3.0	59.1	1.2	39.9	0.4
Improved Charcoal	6.3	2.9	5.8	0.7	1.8	4.3	0.1	6.5	13.5	7.8	-
Industrial Emission Controls	3.5	6.3	3.3	-	-	2.5	1.8	-	-	-	-
More efficient biomass stoves	-	-	-	-	-	-	-	-	-	-	-
NDC Energy Efficiency	0.2	0.3	0.2	0.0	15.0	0.3	1.6	0.0	0.0	0.0	5.1
NDC Renewable Electricity Generation	0.0	0.0	0.1	0.0	25.2	0.3	3.3	0.0	0.0	0.0	10.6
Open Waste Burning	13.3	5.1	11.3	1.1	0.8	10.2	1.7	2.3	1.9	1.6	-
Sulphur Fuel Quality	-	-	-	-	11.1	-	-	-	-	-	-
Switch biomass to gas stoves	21.4	19.0	22.5	2.6	3.8	20.9	2.2	8.0	7.4	9.4	-0.1
Switch to public transport	0.0	-0.3	-0.1	0.0	0.1	-0.1	-0.1	0.3	0.0	1.0	0.5
Tour bus standards	-	-	-	-	-	-	-	-	-	-	-
Air Pollution Circular	51.1	36.4	46.0	3.5	15.8	44.0	12.9	71.8	10.7	58.6	1.8
All Measures	61.7	63.4	60.7	4.2	52.1	55.1	48.0	79.4	24.3	67.8	18.6

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