MALAYSIA

FOURTH NATIONAL COMMUNICATION REPORT (NC4)

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

MINISTRY OF NATURAL RESOURCES AND ENVIRONMENTAL SUSTAINABILITY

MALAYSIA

FOURTH NATIONAL COMMUNICATION REPORT (NC4) UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

This is Malaysia's Fourth National Communication Report (NC4) submitted to the United Nations Framework Convention on Climate Change in April 2024

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UNITS

mm	millimetre
cm	centimetre
m	metre
km	kilometre
km^2	square kilometre
ha	hectare
m^2	cubic metre
g	gram
kg	kilogram
t	tonne
kt	kilotonne
Gg	gigagram
Mt	million tonnes
hr	hour
yr	year
TJ	Tera Joule
PJ	Peta Joule
toe	Tonnes of oil equivalent
ktoe	Kilo tonnes of oil equivalent
Mtoe	Million tonnes of oil equivalent
t CO_2eq	tonnes of carbon dioxide equivalent
kWh	kilowatt hour
MW	megawatt
MWh	megawatt hour
GWh	gigawatt hour
RM	Ringgit Malaysia (Malaysia Ringgit)
°C	degree celcius

CHEMICAL ELEMENTS

C	Carbon
K	Potassium
N	Nitrogen
P	Phosphorous

GASES

CO	carbon monoxide
CO_2	carbon dioxide
CH_4	methane
HFC	hydrofluorocarbon
NF_3	nitrogen trifluoride
N_2O	nitrous oxide
NMVOCs	non-methane volatile organic compounds
NOx	nitrogen oxide
PFC	perfluorocarbon
SF_6	sulphur hexafluoride
SO_2	sulphur dioxide

CONVERSION TABLE

1 tonne	= 10^3 kg	= 10^6 g	
1 k tonne	= 10^6 kg	= 10^9 g	= 1 Gg
1 M tonne	= 10^9 kg	= 10^{12} g	= 10^3 Gg
1 km^2	= 100 ha		
1 TJ	= 10^{12} Joules		
1 PJ	= 10^{15} Joules	= 10^3 TJ	

LIST OF ACRONYMS

ADG	Average Daily Gain
AEA	ASEAN Energy Awards
AFOLU	Agriculture, Forestry and Other Land Use
AGE	Acute Gastroenteritis
AMB	Ambitious
ANCST	Asian Network on Climate Science and Technology
ANN	Artificial Neural Network Architecture
AOGCMs	Atmosphere-Ocean General Circulation Models
APAD	Land Public Transport Agency
APCC	APEC Climate Centre
APEC	Asia-Pacific Economic Cooperation
APMEN	Asia Pacific Malaria Elimination Network
AR4	Fourth Assessment Report (IPCC)
AR5	Fifth Assessment Report (IPCC)
AR6	Sixth Assessment Report (IPCC)
ASEAN	Association of Southeast Asian Nations
ASM	Academy of Sciences Malaysia
BAU	Business as Usual
BLS	Barat Laut Selangor (Northwest Selangor)
BUR	Biennial Update Report
BUR3	Third Biennial Update Report
BUR4	Fourth Biennial Update Report
B5	A blend of 5% palm-based fatty acid methyl ester and 95% petroleum diesel
B7	A blend of 7% palm-based fatty acid methyl ester and 93% petroleum diesel
B10	A blend of 10% palm-based fatty acid methyl ester and 90% petroleum diesel
B20	A blend of 20% palm-based fatty acid methyl ester and 80% petroleum diesel
B30	A blend of 30% palm-based fatty acid methyl ester and 70% petroleum diesel
CBG	Compressed Bio-gas
CBOs	Community-based Organisations
CCA	Community Conserved Areas
CCF	Climate Change Factor
CCU	Carbon Capture and Utilisation
CDM	Clean Development Mechanism
CDV	Canine Distemper Virus
CEEA	Conference of Earth Environment from Akita Japan
CFS	Central Forest Spine
CIDB	Construction Industry Development Board
CMEDT	Cambridge Malaysian Education and Development Trust
CMIP5	Coupled Model Intercomparison Project phase 5
CMIP6	Coupled Model Intercomparison Project phase 6
CNG	Compressed Natural Gas
CO_2 eq.	Carbon Dioxide equivalent

CORDEX	Coordinated Regional Climate Downscaling Experiment
CoT	Crown-of-Thorns
CPG	Clinical practice guidelines
CPRC	National Crisis Preparedness and Response Centre
CRDC	Cocoa Research and Development Centre
CRF	Case Fatality Rate
CSP	Concentrated Solar Power
CTCN	Climate Technology Centre and Network
DAKN	Dasar Agrikomoditi Negara (National Agri-commodity Policy)
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
DKN	Dasar Komoditi Negara (National Commodity Policy)
DMG	Department of Minerals and Geosciences
DNA	Designated National Authority
DoA	Department of Agriculture
DoF	Department of Fisheries
DOE	Department of Environment
DOSM	Department of Statistics Malaysia
DVS	Department of Veterinary Services
DWNP	Department of Wildlife and National Parks of Peninsular Malaysia
EC	Energy Commission
ECC	Emergency Control Centre
EEVs	Energy Efficient Vehicles
EF	Emission Factors
EIA	Environmental Impact Assessment
EIP	Eco Industrial Park
EMS	Environmental Management System
ENSO	El Niño-Southern Oscillation
EPU	Economic Planning Unit (under the Prime Minister’s Department)
ERL	Express Rail Link
ERP	Emergency Response Plan
ESA	Environmentally Sensitive Areas
ESCP	Erosion and Sedimentation Control Plan
ESG	Environment, Social and Governance
ETS	Electric Train Service
EV	Electric Vehicle
EWS	Early Warning System
FACE	Free Air Carbon Dioxide Enrichment
FAOSTAT	Food and Agriculture Organization Statistics
FCR	Feed Conversion Ratio
F-Gases	Fluorinated Gases
FiT	Feed-in-Tariff
FSPV	Floating Solar Photovoltaic
FWBD	Food and Water Borne Disease
FWI	Fire Weather Index
GAW	Global Atmospheric Watch
GCF	Green Climate Fund
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEC	Global Environmental Centre

GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	German Agency for International Cooperation
GNI	Gross National Income
GOG	Gallium nitrate-on-Gallium nitrate
GoT	Gulf of Thailand
GRA	Global Research Alliance on Agricultural Greenhouse Gas Research
GSS	Global Salmonella Surveillance
G x E	Genetic by Environment
HIA	Health Impact Assessment
HoB	Heart of Borneo
HORAS	Hybrid Off-river Augmentation System
IADA	Integrated Agriculture Development Area
ICD-10	International Classification of Diseases 10th Revision
ICE	Internal combustion engine
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IGEM	International Greentech and Eco Products Exhibition and Conference Malaysia
IMR	Institute for Medical Research
IMTA	Integrated Multi-trophic Aquaculture System
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRBM	Integrated River Basin Management
IRDA	Iskandar Regional Development Authority
ISC	International Science Council
ISES	International Sustainable Energy Summit
ISMP	Integrated Shoreline Management Plan
IWRM	Integrated Water Resources Management
IVM	Integrated Vector Management
JBPM	Jabatan Bomba dan Penyelamat Malaysia (Fire and Rescue Department of Malaysia)
JICA	Japan International Cooperation Agency
JKR	Jabatan Kerja Raya (Public Works Department)
JUPEM	Jabatan Ukur dan Pemetaan Malaysia (Department of Survey and Mapping Malaysia)
KADA	Kemubu Agricultural Development Authority
KASA	Kementerian Alam Sekitar dan Air (Ministry of Environment and Water)
KeTSA	Kementerian Tenaga dan Sumber Asli (Ministry of Energy and Natural Resources)
KL	Kuala Lumpur
KLIA	Kuala Lumpur International Airport
KTM	Keretapi Tanah Melayu (Malayan Railways)
KTMB	Keretapi Tanah Melayu Berhad (Malayan Railways Limited)
LCC	Life Cycle Cost
LCD	Litres Per Capita Per Day
LED	Light Emitting Diode
LPWG	Lima Work Programme on Gender

LRT	Light Rail Transit
LSS	Large-Scale Solar
LUAS	Selangor Water Management Board
LULUCF	Land Use, Land Use Change and Forestry
LVC	Low Visibility Condition
MADA	Muda Agricultural Development Authority
MAFI	Ministry of Agriculture and Food Industries
MAFS	Ministry of Agriculture and Food Security
MAGICs	ME Malaria Geo-Reference Information & Coordination System for Malaria Elimination
MAIN	Malaysia Adaptation Index
MARDI	Malaysia Agriculture Research and Development Institute
MCB	Malaysian Cocoa Board
MCO	Movement Control Order
MCSC	Malaysian Commonwealth Studies Centre
MEPS	Minimum Energy Performance Standards
METMalaysia	Malaysian Meteorological Department
MGFT	Malaysian Green Financing Taskforce
MGTC	Malaysia Green Technology and Climate Change Corporation
MHLG	Ministry of Housing and Local Government
MHP	Multi-Hazard Platform
MIGHT	Malaysian Industry-Government Group for High Technology
MITI	Ministry of Investment, Trade and Industry
MNS	Malaysian Nature Society
MOH	Ministry of Health
MSIG	Malaysian Sewerage Industry Guidelines
mmbtu	Million Metric British Thermal Unit
NAVTEX	Navigational Telex
MIGHT	Malaysian Industry-Government Group for High Technology
MISIF	Malaysian Iron and Steel Industry Federation
MNHP	Malaysia National Health Policy
MOH	Ministry of Health
MOT	Ministry of Transport
MPIC	Ministry of Plantation Industries and Commodities
MPOB	Malaysian Palm Oil Board
MPOCC	Malaysian Palm Oil Certification Council
MRB	Malaysian Rubber Board
MRT	Mass Rapid Transit
MRV	Measurement, Reporting and Verification
MSMA	*Manual Saliran Mesra Alam* (Urban Storm Management Manual)
MSPO	Malaysian Sustainable Palm Oil
MyCAC	Malaysia Climate Change Action Council
MyDAMS	Malaysia Dam Safety Management Guidelines
MyFOCI	Malaysia FOCI
myKP	myKomuniti Perikanan
NADMA	National Disaster Management Agency
NAHRIM	National Water Research Institute of Malaysia
NAP	National Automotive Policy
NAP 2.0	National Agrofood Policy 2021-2030
NAVTEX	NAVigational TEleX

NAWABS	National Water Balance Management System
NC	National Communication
NC3	Third National Communication
NC4	Fourth National Communication
NDC	Nationally Determined Contribution
NEB	National Energy Balance
NEEAP	National Energy Efficiency Action Plan
NGOs	Non-governmental Organisations
NIES	National Institute for Environmental Studies (Japan)
NOAA	National Oceanic and Atmospheric Administration (United States of America)
NPP-3	National Physical Plan-3
NPP4	Fourth National Physical Plan
NPS	Network Pumping Station
NREB	Natural Resources and Environment Board
NRES	Ministry of Natural Resources and Environmental Sustainability
NRPP 2030	National Rural Physical Plan 2030
NRW	Non-Revenue Water
NSCCC	National Steering Committee on Climate Change
NSCREDD	National Steering Committee on REDD plus
NSWNP	National Solid Waste Management Plan
NTP	Non-thermal Plasma
NUP-2	Second National Urbanisation Policy
NWP	National Water Policy
NZAGRC	New Zealand Agricultural Greenhouse Gas Research Centre
OISST	Optimum Interpolation Sea Surface Temperature
OPAK	Pool Water Pumping Operation
ORS	Off-River Storage Facility
PA	Protected Area
PCC	Per Capita Consumption
PETRONAS	Petroleum Nasional Bhd (National Petroleum Limited)
PFCs	Perfluorocarbons
PIA	Penang International Airport
PISMA	Pelan Induk Saliran Mesra Alam (Stormwater Management and Drainage Master Plan)
PLANMalaysia	Department of Town and Country Planning
PLUS	Projek Lebuhraya Utara-Selatan (North-South Expressway Project)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
POME	Palm Oil Mill Effluent
PRFs	Permanent Reserved Forests
PV	Photovoltaic
PWD	Public Works Department
RAS	Recirculation Aquaculture System
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
R&D	Research and Development
RegHCM	Regional Hydro-Climate Model
RegHCM-PM	Regional Hydro-Climate Model-Peninsular Malaysia
RegHCM-SS	Regional Hydro-Climate Model-Sabah and Sarawak

RE	Renewable Energy
REDD Plus	Reducing Emissions from Deforestation and Forest Degradation, and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries
RE-SSN	Renewable Energy Sub-Sector Network
RIDM	Risk Informed Decision Making
RU-CORE	Ramkhamaheng University Centre of Regional Climate Change and Renewable Energy (Bangkok)
RVI	Rainfall Variability Index
SAM	Sahabat Alam Malaysia (a Malaysian NGO)
SARCCIS	Southeast Asia Regional Climate Change Information System
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goals
SEADPRI-UKM	Southeast Asia Disaster Prevention Research Initiative-Universiti Kebangsaan Malaysia
SEB	Sarawak Energy Berhad
SEACLID	Southeast Asia Climate Downscaling
SEADPRI	Southeast Asia Disaster Prevention Research Initiative
SEDA	Sustainable Energy Development Authority
SHADOZ	Southern Hemisphere Additional Ozonesondes (Network)
SIA	Social Impact Assessment
SIRIM	Standard and Industrial Research Institute of Malaysia
SLF	State Land Forests
SLR	Sea Level Rise
SME Corp	Small and Medium Enterprise Corporation
SOP	Standard Operating Procedure
SPAD	Land Public Transport Commission
SPAN	National Water Services Commission
SPWD	Sistem Pengurusan Wabak Denggi (Dengue Outbreak Management System)
SSL	Self Sufficiency Level
SSP	Socio-Economic Pathway
SST	Sea Surface Temperature
STP	Sewage Treatment Plant
SWG/SWGs	Sub-Working Group/ Sub-Working Groups
TA	Technical Assistance
TCCC	Technical Committee on Climate Change
THI	Temperature-Humidity-Index
TMP	Tun Mustapha Park
TNB	Tenaga Nasional Berhad
TNBR	Tenaga Nasional Berhad Research
TPA	Totally Protected Area
TPRL	Tropical Peat Research Laboratory (Sarawak)
TROPI	Tropical Peat Research Institute (Sarawak)
TTE	Team of Technical Experts
TWG/TWGs	Technical Working Group/Technical Working Groups
TWN	Third World Network
UK	United Kingdom
UKM	Universiti Kebangsaan Malaysia (National University of Malaysia)
UM	Universiti Malaya (University of Malaya)

UMS	Universiti Malaysia Sabah (University of Malaysia Sabah)
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNDRR	United Nations Office for Disaster Risk Reduction
UNIDO	United Nations Industrial Development Organisation
UNITEN	Universiti Tenaga Nasional
V&A	Vulnerability and Adaptation
VBIAF	Value based Intermediation Financing and Investment Impact Assessment Framework
VTS	Vessel Traffic Services
WAM	With Additional Measures
WASH FIT	Water and Sanitation for Health Facility Improvement Tool
WCC	Wildlife Conservation Centre
WEM	With Existing Measures
WEPLS	Water Efficient Products Labelling Scheme
WGIA	Workshop on Greenhouse Gas Inventories in Asia
WIA	Wildlife Impact Assessment
WMO	World Meteorological Organisation
WOUDC	World Ozone and Ultra-violet Radiation Data Centre
WOM	Without Measures
WRF	Weather Research Forecasting (Model)
WRF-PM	Weather Research Forecasting (Model)-Peninsular Malaysia
WRF-PM	Weather Research Forecasting (Model)-Sabah and Sarawak
WST 2040	Water Sector Transformation 2040
WTD	Water Table Depth
WTP	Water Treatment Plant
WUE	Water Use Efficiency

FULL NAMES OF GCMS REFERRED IN CHAPTER 4

Name of GCM (AR4)	Full description
CGCM3.1	Canadian Global Coupled Model Version 3.1
GISS-AOM	Goddard Institute for Space Studies Atmosphere Ocean Model
GISS-ER	Goddard Institute for Space Studies Model E, Version R
MIROC3.2 (hires)	Model for Interdisciplinary Research on Climate model 3.2 in high resolution
MIROC3.2 (medres)	Model for Interdisciplinary Research on Climate (Japan) version 3.2, in mid-range resolution
MI-CGCM3.2a	Meteorological Research Institute (Japan) version 3.2a

Name of GCM (AR5)	Full description
ACCESS1-0	Australian Community Climate and Earth System Simulator version 1
ACCESS1-3	Australian Community Climate and Earth System Simulator version 1.3
CanESM2	Second generation Canadian Earth System Model
CCSM4	Community Earth System Model (CESM) subset from CESM1
CESM1-BGC	Community Earth System Model, version 1 in Biogeochemistry
CESM1-CAM5	Community Earth System Model in simulating the cloud-aerosol indirect radiative effects
CMCC-CESM	Centro Euro-Mediterraneo per I Cambiamenti Climatici Earth System Model T31L39
CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici Earth System
CNRM-CM5	Centre National de Recherches Me´te´orologiques (France) exercise 5
CSIRO-MK3-6-0	Commonwealth Scientific and Industrial Research Organisation version 3.6
FGOALS-g2	Flexible Global Ocean-Atmosphere-Land System model (FGOALS) (China), grid point version 2
FIO-ESM	First Institute of Oceanography Earth System Model (FIO-ESM) version 2.0
GFDL-CM3	Geophysical Fluid Dynamics Laboratory Climate Model version 3
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory Earth Simulation Model with pressure depth-based vertical coordinate (and used along the developmental path of GFDL's Ocean Model Version 4.1; MOM4.1)
GISS-E2-R	Goddard Institute for Space Studies Model E/Russell 2×2.5×L40.
HadGEM2-CC	Hadley Centre Global Environment Model version 2 in specific Carbon Cycle configuration

HadGEM2-ES	Hadley Centre Global Environment Model version 2 Earth Simulation Model (for long-term mean monthly precipitation simulation)
INMCM4	Institute for Numerical Mathematics of Russia Climate Model version 4
IPSL-CM5A-LR	Institut Pierre-Simon Laplace of France model 5A in low resolution
IPSL-CM5A-MR	Institut Pierre-Simon Laplace of France model 5A in medium resolution
IPSL-CM5B-LR	Institut Pierre-Simon Laplace of France model 5B in low resolution
MIROC5	Model for Interdisciplinary Research on Climate, model version 5
MIROC-ESM	Model for Interdisciplinary Research on Climate – Earth Simulation Model, with atmospheric and aerosol interactions
MIROC-ESM-CHEM	Model for Interdisciplinary Research on Climate – Earth Simulation Model, with atmospheric chemistry coupled version of MIROC-ESM

FOREWORD

It is with deep dedication and an unwavering commitment to global climate action that Malaysia presents its Fourth National Communication (NC4) to the United Nations Framework Convention on Climate Change (UNFCCC). This comprehensive document not only delves into the latest estimations of anthropogenic Greenhouse Gas (GHG) emissions and removals but also outlines Malaysia's evolving climate change efforts across crucial sectors such as Energy, Industrial Processes and Product Used (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste. The NC4 of Malaysia was prepared according to the 17/CP.8 decision.

As we embark on this journey towards transparency and accountability, the Ministry has intensified its efforts to align with the Enhanced Transparency Framework (ETF) outlined in Article 13 of the Paris Agreement. This signifies a pivotal step in ensuring that our reporting adheres to the highest standards of transparency, accuracy, completeness, comparability and consistency, reflecting our commitment to the global climate community.

I extend my heartfelt gratitude to the multitude of experts and stakeholders whose cooperation and commitment made the preparation of this report possible. The invaluable data provided by government ministries, agencies, research organizations, corporations, industry associations, universities, and non-governmental organizations underscores the collective effort required to address the challenges of climate change. Special recognition is extended to the National and Technical Steering Committees on Climate Change, as well as the Technical and Sub-Working Groups, for their dedication and diligence.

In closing, I express sincere appreciation to the UNFCCC, Global Environment Facility (GEF), and United Nations Development Programme (UNDP) for their facilitation in bringing this report to fruition. Together, let us look forward to continued cooperation, ensuring that Malaysia not only meets but exceeds its obligations under the Paris Agreement. May this report serve as a testament to our shared commitment to a sustainable and resilient future for all.

NIK NAZMI BIN NIK AHMAD
Minister of Natural Resources and Environmental Sustainability

EXECUTIVE SUMMARY

Introduction

Malaysia's Fourth National Communication (NC4) is prepared according to the guidance United Nations Framework on Climate Change (UNFCCC) Decision 17/CP.8. The report provides information on National Circumstances, National Greenhouse Gas (GHG) Inventory, Mitigation Assessment, Vulnerability Assessment and Adaptation Measures, Research and Systematic Observation, Capacity-building, Education, Public Awareness, Information-sharing and Networking and Constraints, Gaps, Level of Support Received and Needs.

The chapter on Vulnerability Assessment and Adaptation Measures is concurrently submitted as Malaysia's First Adaptation Communication pursuant to the Paris Agreement, which was prepared taking into account Decision 9/CMA.1.

1. National Circumstances

Information on the country's national circumstances up to the year 2019 was provided where relevant geography, climate, natural resources, social and economic published statistics were available. The chapter also communicates the status of key climate-related sectors and their respective policies and strategic measures as well as Malaysia's political system and climate governance structure.

Malaysia is located in the Southeast Asia region and lies between 0º 51' N and 7º 33' N, and 98º 01' E and 119º 30' E. It has a land area of 330,241 km^2 with about 8,840 km of coastline. It has a tropical maritime climate and consistent with global warming trends, there has been a surface mean temperature increase of 0.13 ºC to 0.24 ºC per decade in the past 50 years. For the same period of half a century, annual rainfall averages about 2,000 mm to 4,000 mm with a slight downward trend for Peninsular Malaysia and Sabah while in Sarawak, there is a slight increasing trend.

Between 1986 and 2021, the average annual sea level rise in Peninsular Malaysia was 3.2 mm per annum while from 1988 to 2021 it was 2.9 mm per annum for Sabah. Sarawak and the Federal Territory of Labuan.

Malaysia has upheld its voluntary pledge of maintaining 50% of its landmass as forest since the 1992 Earth Summit and in 2019, approximately 54.9% of the land remained forested. As a mega biodiverse country, terrestrial biodiversity is supported by the high forest cover while aquatic biodiversity is found in the varied marine ecosystems.

Malaysia's population has been growing quite steadily in the past 15 years, reaching 32.5mil in 2019. Population density increased from 79 person per km^2 in 2005 to 99 persons per km^2 in 2019. The national urbanisation rate grew from 51.4% in 1990 to 76.2% in 2019. In 2019, 23.5% of the population was under 15 years old, 69.8% were between the ages of 15 and 64, and a smaller percentage of 6.7% were over 65 years old. Female life expectancy has increased to 77.4 years in 2019 from 76.0 years in 2005 while male life expectancy increased marginally from 71.4 years in 2005 to 72.5 years in 2019.

Gross Domestic Product (GDP) at 2015 constant prices grew from RM729.85 billion in 2005 to RM1,423.95 billion in 2019. The main contributing sectors were services (58.3%), manufacturing (22.5%), mining and quarrying (7.3%), agriculture, livestock, forestry and fishery (7.2%) and construction (4.7%).

The energy sector is anticipated to strengthen access to affordable, reliable and sustainable energy, in line with Sustainable Development Goal 7 of the 2030 Agenda for Sustainable Development. The National Energy Policy 2022 – 2040, introduced in September 2022 underscores the commitment towards energy transformation with a focus to shift from fossil-based systems of production and consumption to renewable energy. The policy aligns the energy sector to the country's long-term plan of Shared Prosperity Vision 2030 and its five Key Economic Growth Activities which are directly related to the energy sector (such as sustainable mobility, renewable energy and green economy). The policy aims to spur new energy-related sectors which will also support the goal of reducing dependence on petroleum-based revenue and commodity trade, enhancing the resilience of the country's fiscal and economic position in the process. The policy also sets the directive towards Low Carbon Nation Aspiration 2040 from the improvement of primary energy mix intensity through increased penetration of clean and renewable sources of energy. This is in line with the Government's target to reach 31% of RE installed capacity mix by 2025.

For the transport sector, the Land Public Transport Agency (APAD) is tasked with 'spearheading the transformation of an integrated, efficient and safe transportation system'. A National Transport Policy (2019-2030) was launched to increase the public transport modal share (40% by 2030) in urban areas while also implementing sustainable measures across all transport modes. Towards this end, the rail network is crucial to the Malaysia's transport system as it enables greater domestic mobility. By the end of 2016, there were five urban rail network lines serving the Greater Kuala Lumpur area namely KTM Komuter, LRT Ampang Line, LRT Kelana Jaya Line, KL Monorail and the MRT.

In the agriculture sector, sustainable development is a key principle in both the food production and commodity sub-sectors. Oil palm remains the most economically important crop followed by rubber. Paddy is also an important agricultural crop and the planted areas of 672,000 hectares as of 2019 involved double cropping. Livestock population size fluctuation across all animal types has largely remain stable between 2015 and 2019. Landings of marine fish in Malaysia has had a slight increase from 1.21 million tonnes in 2005 to 1.45 million tonnes in 2019. Aquaculture production in Malaysia increased from 207,000 tonnes in 2005 to 412,000 tonnes in 2019.

According to the latest national survey in 2012, Malaysians generate 33,10 tonnes per day of waste on average. There were 19 sanitary and 119 non-sanitary landfills in the country in 2019.

Finally, in terms of institutional arrangement, the Malaysia Climate Change Action Council (MyCAC) was established to address the policy direction of climate change in December 2020. It is chaired by the Prime Minister and has key Cabinet Ministers and state leaders as members.

The Cabinet is the highest policy decision-making body in the country on climate change matters under the purview of the Minister of Natural Resources and Environmental Sustainability (NRES). Any decisions taken at the MyCAC and other bodies require a final endorsement by the Cabinet.

Development planning and implementation is coordinated by the Ministry of Economy in consultation with other Ministries. These are carried out through the five-year development plans and include climate change mitigation and adaptation programmes.

Operational matters on climate change are guided and endorsed by the National Steering Committee on Climate Change (NSCCC) chaired by the Secretary General of NRES. The coordination for the preparation of National Communications (NCs) and Biennial Update Reports (BURs) is under the Technical Committee on Climate Change (TCCC) which reports to the NSCCC. The secretariat to these committees is the Climate Change Division of NRES which is also the national focal point for climate change to the UNFCCC. The technical work of the NCs and BURs is carried out through six Technical Working Groups (TWGs) established under the TCCC.

2. National Greenhouse Gas Inventory

Malaysia's national GHG inventory in 2019 using the IPCC AR4 100-year time horizon global warming potential (GWP) values is as follows:

Table ES 1: Malaysia's GHG Inventory using IPCC AR4 for the year of 2019

Sector	GHG Emissions ($Gg\ CO_2$ eq.)
Energy	**259,326.11**
IPPU	**32,853.80**
AFOLU-Agriculture	**9,921.71**
AFOLU-LULUCF	**-214,714.54**
Waste	**28,256.59**
Total (Excluding LULUCF)	**330,358.21**
Total (Including LULUCF)	**115,643.68**

Excluding LULUCF, the total GHG emissions in 2019 was 330,358.21 Gg CO_2 eq. The energy sector continued to be the largest emitter of GHG where it accounted for 78% of the total emissions. This is followed by the IPPU and the waste sectors, at about 10% and 9% of the total emissions respectively. The agriculture sector contributed the lowest emissions at 3%. About 81% of the total GHG emissions were in the form of CO_2, followed by CH_4 at 15% and N_2O and F-gases at about 2% each respectively. Taking into account the LULUCF sector which shows a net sink of -214,714.54 Gg CO_2 eq., Malaysia's net GHG emissions was 115,643.68 Gg CO_2 eq.

Comparison was also carried out between using IPCC AR4 100-year time horizon and IPCC AR5 100-year time horizon GWP for the 2019 GHG inventory. The total CO_2 eq. GHG emission is slightly higher using AR5 GWPs compared to using AR4 GWPs. Excluding LULUCF, the total 2019 GHG emission was 335,059.05 Gg CO_2 eq. using

AR5 GWPs compared to 330,358.21 Gg CO_2 eq. using AR4 GWPs, giving a difference of 1.42%. Including LULUCF, the total 2019 GHG emission was 120,344.51 Gg CO_2 eq. using AR5 GWPs compared to 115,643.68 Gg CO_2 eq. using AR4 GWPs, giving a difference of 4.06%. By sector, the largest difference of 11.64% was observed in the waste sector due to the higher AR5 GWP value of 28 for methane (CH_4) compared to the AR4 GWP value of 25.

The GHG emission time series from 1990 to 2019 (based on IPCC AR4 100-year time horizon GWP) is shown below. As part of the efforts to improve the GHG estimations to the extent possible, recalculations were undertaken and reported in all the sectors as data became available. The energy sector remained the main source of GHG emissions while the LULUCF remained the main sink throughout the time series. The time series indicated that Malaysia's net total GHG emissions became a net source at around the 2004 timeline.

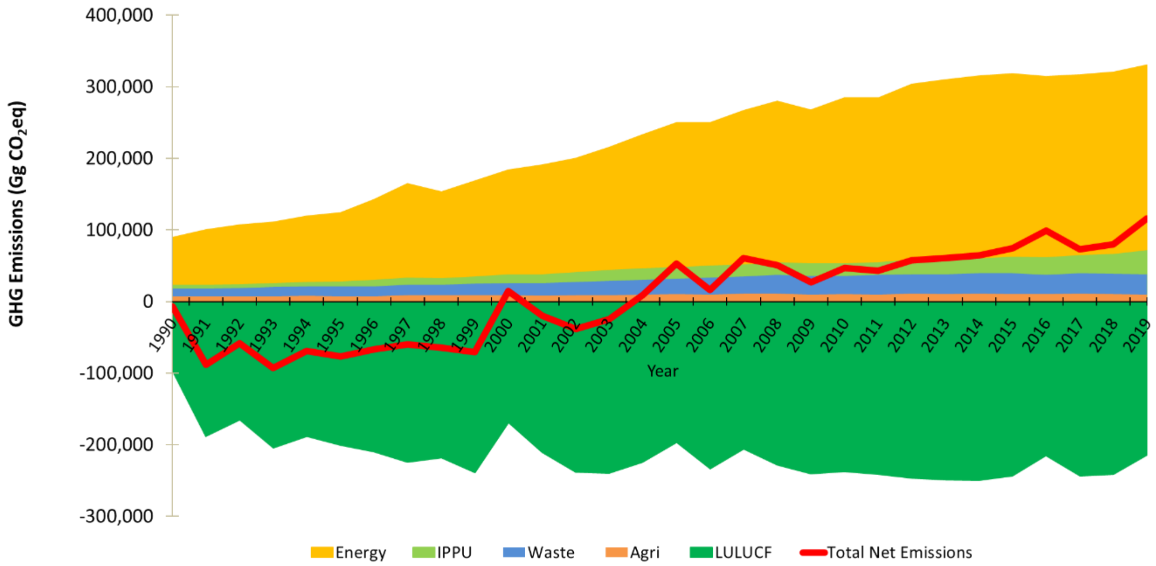


Figure ES 1: Malaysia' GHG Emission Time Series

3. Mitigation Assessment

During the preparation works of NC4, actual energy data for the year of 2020 was still in the process of publication by the related agency. Hence, the projection for the year of 2020 and onwards is based on the pre-COVID-19 condition assumptions.

The updates pertaining to the actual energy data for 2020 and 2021 as well a relatively updated projection will be reported in the next reporting document e.g. the First Biennial Transparency Report (BTR1).

The main mitigation actions and their related policies have been highlighted and the projection exercise were conducted for 3 scenarios. The projection indicates that the total emissions excluding LULUCF for Malaysia would be 481,363 Gg CO_2 eq for the Without Measures (WOM) case by 2030 continued implementation of the planned activities under the With Existing Measures (WEM) scenario would bring the emissions down to 367,603 Gg CO_2 eq. If further mitigation activities under the With Additional Measures (WAM) scenario are carried out, the GHG emissions could reduce to 337,554 Gg CO_2 eq as shown the Figure ES 2.

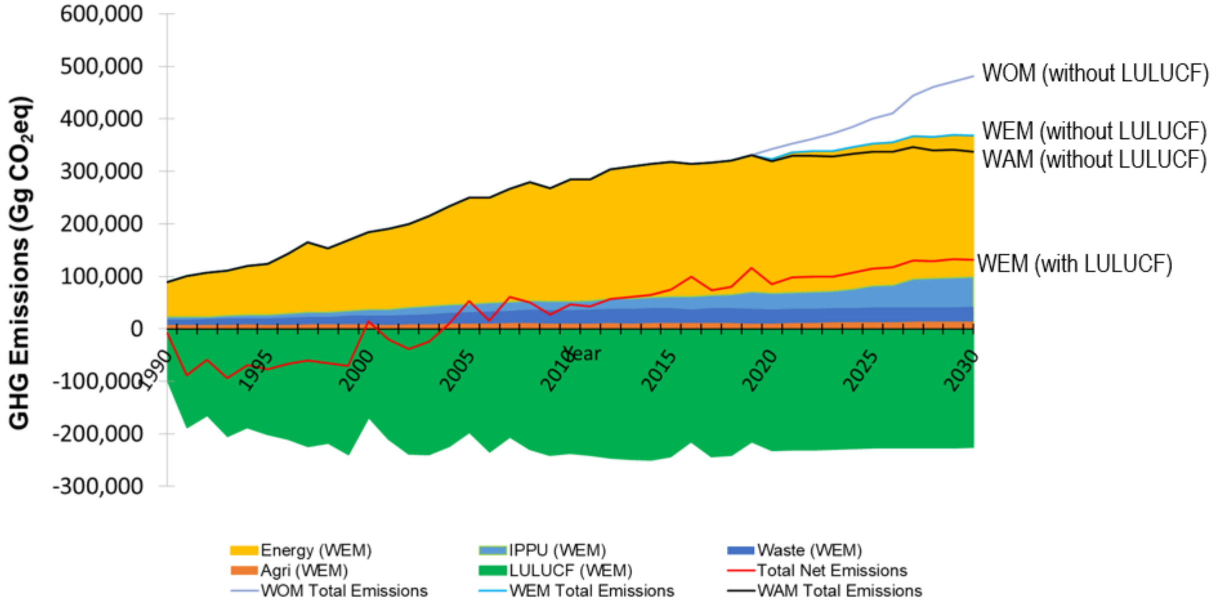


Figure ES 2: Projected Greenhouse Gas Emission Time Series for WOM, WEM and WAM Scenarios

With LULUCF, the total emissions would be 260,431 Gg CO_2 eq for WOM scenario, 141,883 Gg CO_2 eq for the WEM scenario and 105,317 Gg CO_2 eq for the WAM scenario in 2030.

Quantification of mitigation actions will require certain capacity building since certain policies do not have direct GHG mitigation effects. Hence, the supporting policies have to be enhanced to strengthen Malaysia's capability to achieve its Nationally Determined Contribution (NDC) target in 2030.

4. Vulnerability Assessment and Adaptation Measures

The vulnerability assessments of floods, dry spells, sea level rise and coastal inundations due to climate change reported in this chapter are focused on six sectors, namely (i) water and coastal resources; (ii) agriculture and food security; (iii) forestry and biodiversity; (iv) cities, built environment and infrastructure; (v) energy; and (vi) public health. The current adaptation measures, gaps and improvement plans for each of the sectors are also elaborated in the chapter.

Hydroclimate Data and SLR Projections

The sectoral flood and dry spell vulnerabilities were assessed based on the projected future hydroclimate data from the Regional Hydro-Climate Model (RegHCM) with horizontal resolution of 6 km, downscaled from five Global Climate Models (GCMs), based on the IPCC Fifth Assessment Report (AR5) RCP scenarios. Flood areal extent maps of the selected 37 major river basins were developed for flood impact assessment; while the impact of dry spells, extreme dry events and extreme wet events, indicated by rainfall variability index (RVI), were assessed for the whole country on a monthly and annual basis. The SLR along the country's coastlines were projected using 29 Atmosphere-Ocean General Circulation Models (AOGCMs) based on the IPCC Fifth Assessment Report (AR5) RCP scenarios. The coastal inundation maps were then developed for sectoral coastal inundation assessments. In terms of assessment timelines, the flood assessments were carried out for the baseline timeline (1971-2000) and the future timeline up to 2100. The dry spell assessments were carried out for the periods of early-century (2020-2046), mid-century (2047-2073) and late-century (2074-2100), while the SLRs were assessed for the baseline timeline (2022), 2050 and 2100. The respective regional distribution values, at the baseline timeline, of the projected average annual air temperature, average annual rainfall and SLR used in the assessments, are shown in Table ES 1.

Table ES 2: Regional baseline and projected average annual air temperature, average annual rainfall and SLR in Malaysia

Region	Baseline (1971 - 2000)	Early-century	Mid-century	Late-century
Average Annual Temperature (oC)				
Peninsular Malaysia	**24.1**	**24.8**	**25.4**	**25.9**
Sabah	**22.5**	**23.1**	**23.8**	**24.4**
Sarawak	**23.9**	**24.6**	**25.2**	**25.9**
Average Annual Rainfall (mm)				
Peninsular Malaysia	**2,485**	**2,628**	**2,726**	**2,760**
Sabah	**3,208**	**3,467**	**3,649**	**3,779**
Sarawak	**3,349**	**3,734**	**3,843**	**3,963**

Region	Baseline (2022)	By 2050	By 2100
Average Sea Level Rise (m)			
Peninsular Malaysia (west coast)	**0.07**	**0.22**	**0.69**
Peninsular Malaysia (east coast)	**0.07**	**0.23**	**0.70**
Sabah	**0.07**	**0.25**	**0.73**
Sarawak	**0.07**	**0.24**	**0.72**

Water and Coastal Resources

For the water and coastal resources sector, climate change vulnerabilities of reservoir storage and dam security, groundwater security, flood risk management and coastal erosions, were continually assessed. The projected higher number of water supply dams affected by dry spells by mid-century and late-century could lead to more water supply issues in the future, while the higher number of projected water supply dams affected by extreme wet weather by late-century could result in more downstream flooding and affecting dam integrity.

Currently, 5,496 flood hotspots have been identified all over the country. Based on the flood areal extent projections for the 232,001 km^2 of flood prone area in the country, 8.9% of these areas could be at flood risk by 2100, as compared to 6.5% at the baseline timeline. The number of flood hotspots will certainly be increased in the future. Flood risk could be further worsened with coastal flooding due to SLR, which was projected to increase along the country's coastlines by 2050 and 2100.

SLR is also the major threat to groundwater due to saltwater intrusion into the aquifers. Preliminary assessments indicate that 44 and 68 out of the 2,017 tube wells assessed in the country could be vulnerable to SLR by 2030 and 2050, respectively. Coastal erosion could be envisaged to worsen through SLR inundation. The coastal inundation estimated based on SLR projections showed that the west coast shorelines of Peninsular Malaysia could be more vulnerable compared to the east coast shorelines by 2100. Significant coastal inundations were also projected along the Kudat-Sandakan coastline in Sabah, and the Miri-Bintulu and the Bintulu-Sejingkat coastlines in Sarawak, for the same timeline.

Agriculture and Food Security

The agriculture and food security assessments covered rice production and planted area, oil palm planted area, rubber planted area, cocoa cultivation, livestock, and fisheries and aquaculture. The major rice granary areas of MADA, KADA and IADA Barat Laut Selangor could face significant reductions in average rice yield productions of 16.0-39.2% and 7.2-30.1% during the main season and off-season, respectively, by late-century based on the projected temperature, rainfall and solar radiation. Among the granaries, the KADA is anticipated to be the most affected granary by dry spells with projected dry periods from mid-decade of 2020s to late-decade of 2040s. Assessments on floods at the rice planted areas in Peninsular Malaysia indicated projected increment of 7,929 ha of flood prone planted areas and 0.46 m flood depth by 2100, while SLR assessment indicated further additional 10,910 ha and 42,303 ha of inundation by 2050 and 2100, respectively.

Increments in future flood prone planted areas were also projected for the oil palm and rubber sector. SLR impact assessment on the planted areas of these commodity crops also showed increasing trend. Based on the extreme wet weather assessment, rubber plantations in Pahang are amongst the most affected areas by extreme high rainfall. Future dry spells were projected to occur in the oil palm planted areas at the Pahang River basin and Coastal 4 region, and the rubber planted areas at Kedah River basin, Coastal 12 region, Perak River basin, Muar River basin, Pahang River basin and the Kelantan River basin. For the cocoa crop, long-term observation is mandatory to assess the impact of climate change on its production. Initial research showed that temperatures greater than 36ºC affects cocoa pod production.

Extreme weather events such as intense rainfalls will lead to emergence of water-related diseases affecting livestock. Heat stress due to prolonged dry spells will result in reductions in productivity and reproductive efficiency of livestock. Local research found that severe heat stress at a Temperature-Humidity-Index (THI) equals to 93, will affect milk production of dairy cattle. Further increase in THI readings exceeding 100 can result in livestock mortality.

For fisheries and aquaculture, the freshwater culture systems in Johor and Perak were projected more prone to floods up to 2100. The systems In Perak could also be affected with SLR inundations by 2050. In Johor, Kedah and Selangor, the freshwater culture ponds were projected to have higher risk exposure to SLR by 2100. For brackish water culture systems, the systems in Terengganu, Negeri Sembilan, Sabah and Sarawak were projected more prone to SLR by 2100. Assessments of dry spell indicated that both freshwater and brackish water culture systems at the Kelantan River basin, Pahang River basin, Linggi River basin and Muar River basin could be affected with projected prolonged dry spells during some particular years, up to 2050.

Forestry and Biodiversity

In Malaysia, forest fires could be exacerbated by prolonged dry spells lasting at least four months or more. Assessments of dry spells showed that extra attention and monitoring needs to be addressed at the peat swamp forest reserves in Peninsular Malaysia by mid-century and late-century; Sabah, specifically in the Kulamba Wildlife and Kulamba Wildlife Reserve (Extension), by early-century; and Sarawak, by early-century and mid-century. Forests located along the coastlines and coastal areas could be susceptible to SLR, coastal inundation and salt-water intrusion. Increasing areal extent of SLR prone mangrove forest reserves, peat swamp forests and inland forest reserve areas in Peninsular Malaysia from the current timeline (2022) to 2050, and then to 2100, were projected. A similar trend is anticipated in Sabah and Sarawak.

Terrestrial fauna survival responds to climate change through migration or adaptation. It was documented that various species of moth native have migrated to Mount Kinabalu uphill, following temperature zones as a consequence of global warming. Genetic isolation due to degradation of surrounding environment may cause extinctions of some local terrestrial fauna populations over a long-term period. The loss of ecological connectivity due to fragmentation of forest has affected animal and plant populations, where over time could increase their vulnerabilities to climate change. Unexpected forest fires due to prolonged dry spell also threaten the terrestrial fauna. However, the direct impact of climate change on terrestrial fauna biodiversity and the ecosystem health is still unclear.

For the marine ecosystems, the annual coral reef health survey conducted in 2021 showed improvements in reef health with a “fair” level of average live coral cover of 44.26%. As such, periodic site closures could be recommended and mandatory as a management improvement recovery measure in future. In Sabah, the decline of hawksbill turtles is a disturbing sign observed at the Turtle Island Park due to the loss of the nesting beach, which had suffered severe beach erosion. Further research on impact of SLR on the marine mammals at Tun Mustapha Park needs to be conducted and advised.

Cities, Built Environment and Infrastructure

According to PLANMalaysia, as of 2022, there are 281 towns and cities in Peninsular Malaysia. In the rainy seasons, evening flash floods are common in the towns and cities in the west coast of Peninsular Malaysia; whilst, over at the east coast, floods brought about by the north-east monsoon are the more common flood events. Assessment of floods in these towns and cities indicated that 86 and 96 of them, are flood prone at baseline timeline (1971-2000) and up to 2100, respectively. The projected floods could also affect 75,927 ha of the built environment areas in Peninsular Malaysia at baseline timeline (1971-2000), and this is expected to increase to 96,563 ha up to 2100. The SLR assessments indicated that 111 towns and cities along the coastlines are prone to SLR at current timeline (2022) and by 2050, and this number is expected to increase to 116 by 2100. There was about 50,200 ha of built environment assessed to be affected by SLR at current timeline (2022). At the future timeline scenarios, the affected areas were projected to increase to 65,917 ha by 2050 and 99,774 ha by 2100. Malaysia had in early century also experienced dry spells a number of times. This was also indicated by the dry spell assessments where 25 towns and cities were projected to face extreme dry weather in early-century. The projected number is expected to reach 57 and 68 by mid-century and late-century, respectively. It is also estimated that 51,373 ha of built environment areas are prone to dry spells in early-century, and could increase to 203,024 ha by mid-century and 229,140 ha by late-century.

Assessments of the impact of climate change on infrastructure is centred on roads, rails, ports and jetties, and airports. At the baseline timeline (1971-2000), there were about 1,111 km of roads and highways projected prone to floods, including the Pan Borneo Highway in Sabah and Sarawak, and this is expected to increase to 1,325 km up to 2100. Floods could also affect 20 railway stations with about 183.5 km of railway section length, up to 2100. The majority of the airports in Sabah and Sarawak, and some airports in Peninsular Malaysia, were projected as flood prone, at both timelines. The SLR assessments indicated that some stretches of the coastal roads, highways and railways in Peninsular Malaysia are vulnerable to SLR throughout the century. There were 21 and 22 ports and jetties/ferry terminals projected to be prone to SLR at the current timeline (2022) and by 2050, respectively. An additional 11 ports and jetties/ferry terminals, the majority of which are from Sabah, is expected to be affected by 2100. The Penang International Airport is also expected to face SLR inundation by 2050 and 2100. Assessments of dry spells indicated that five ports and jetties/ferry terminals are vulnerable to prolonged dry spells at some particular years during mid-century, and the number is expected to reach 13 by late-century.

Public facilities such as solid waste facilities, sewerage facilities and water supply facilities are also vulnerable to climate change. The flood areal extent maps indicated that some waste disposal sites are prone to floods up to 2100. Floods could also affect 60 and 71 sewerage facilities at the current timeline (1971-2000) and up to 2100, respectively. Selangor is expected to have the highest number of affected sewerage facilities at both timelines. As for water supply facilities, 47 and 56 facilities were projected to be flood prone at the two respectively timelines. Assessments of SLR showed that four solid waste facilities could be affected by SLR at current timeline (2022) and by 2050. Four additional sites are expected to be affected by 2100. The projected numbers of sewerage facilities that could be inundated due to SLR at current timeline, by 2050 and by 2100 were 402, 488 and 835 units, respectively. However, SLR has no clear impact on the water supply facilities. Assessments of dry spells indicated seven solid waste facilities are vulnerable in some particular years by early-century. Three additional facilities are expected to be vulnerable by mid-century and late-century. The projected numbers of water supply facilities that could be vulnerable to prolonged dry spells at current timeline, by 2050 and by 2100 were 11, 28 and 38 units, respectively. There is no immediate direct impact on the sewerage facilities due to dry spells. For flood relief centres, there could be 708 and 910 centres located in Peninsular Malaysia vulnerable to floods at baseline timeline (1971-2000) and up to 2100, respectively.

Energy

Currently, there are 18 hydropower plants and 31 thermal power plants, each with 50 megawatts and above of capacity, in the country. Based on the flood areal extent maps, some of the plants located in Perak, Kelantan and Selangor were projected to be flood prone at baseline timeline and up to 2100. The operation of hydropower plants and thermal power plants is also affected by extreme wet weather and dry spells. Climate projection throughout the century had indicated a total of 20 hydropower plants located in Perak, Kelantan, Pahang, Terengganu, Sabah and Sarawak that could be affected by extreme wet weather. The same plants that are located in Perak, Pahang, and Sarawak could also be affected by dry spells. For thermal power plants, the plants located in Selangor, Johor, Negeri Sembilan, Perak, Pulau Pinang and Putrajaya are anticipated to face extreme wet weather and/or dry spell problems. Some of these thermal power plants that are located in Selangor, Johor, Pulau Pinang and Negeri Sembilan could also be SLR prone as well. The projected number of flood prone substations in Peninsular Malaysia could substantially increase from 5,897 substations at baseline timeline to 7,093 substations up to 2100. Meanwhile, SLR projection indicated that 4,137 substations are currently SLR prone. This number is expected to increase to 4,991 and 8,003 by 2050 and 2100, respectively.

For the oil and gas industry, the number of probable flood prone PETRONAS assets was projected to increase from 111 at baseline timeline (1971-2000) to 132 up to 2100. SLR impact assessment had indicated 44 assets along the coastal areas of Peninsular Malaysia that are SLR prone at current timeline (2022), and it is expected to increase to 55 and 83 by 2050 and 2100, respectively. Future dry spell impact assessments had indicated a total of 70 assets could be vulnerable to dry spells, in some particular years by late-century. Extreme high temperature would lead to heat stress on operations and the work comfortability of staff. Assets located in Gurun, Melaka, Pengerang, Gebeng, Kerteh, Bintulu, Miri and Labuan are anticipated susceptible to this projected extreme temperature change.

Public Health

For the public health sector, climate change impacts such as floods and SLR do pose a significant threat to the healthcare facilities. There were 17 hospitals and 125 health clinics projected to be flood prone at baseline timeline (1971-2000), and these numbers are expected to increase to 19 hospitals and 149 health clinics, respectively, up to 2100. The impact assessments of SLR showed that four hospitals were prone to SLR at current timeline (2022) and 2050, and four additional SLR prone hospitals are expected to be prone by 2100. Health clinics could be more vulnerable to SLR inundations. This is shown by the projected increments of 5 and 37 affected health clinics by 2050 and 2100, respectively. For climate sensitive diseases such as dengue, malaria, food and water borne diseases, leptospirosis, and heat related illness, continuous monitoring and prevention are being carried out, as part of the prevailing public health responses to climate change.

Gaps and Improvement Plan

The majority of the gaps identified in the NC3 have been fulfilled during the NC4 period. The flood areal extent maps for 17 river basins in Peninsular Malaysia, 10 river basins in Sabah and 10 river basins in Sarawak, were all developed for flood impact assessments of all sectors mentioned. For the dry spell and extreme wet weather impact assessments, monthly and yearly rainfall indices were developed for the whole country.

There is need for continual updating and improvement of the hydroclimate models to enable more accurate projections. For the SLR, coastal flood inundation maps and saltwater intrusion simulations using a two-dimensional numerical coastal hydrodynamic model would be developed. Phenomenon arising from interaction of SLR, storm surges, abnormally high tides and high rainfall events can be studied using a numerical river and coastal hydrodynamic model which is important for assessments of severe coastal flooding. Development of a comprehensive assets database hub covering the entire country, and the specific sectoral tools and modelling, for sectoral assessment purposes are crucial and urgent.

For capacity building, a dedicated team and facilities for developing assessment tools and carrying out sectoral and cross-sectoral assessment exercises would have to be engaged and established. Continuous full-scale programmes and activities to understand the full chain of climate change implications at the state and local governmental levels are important. As part of the plan for improvements, a comprehensive National Adaptation Plan (NAP) that integrates elements of disaster risk reduction from the Sendai Framework and the Sustainable Development Goals would continue to be developed, to guide systematic implementation of no-regret adaptation measures for all the sectors.

5. Research and Systematic Observation

Malaysia recognised the urgency and has prioritised scientific research, long-term systematic monitoring and data collection for informed policy directions to undertake the necessary response measures.

Research

Over the past decade, research institutes, universities, NGOs and the private sector had continued with their respective research activities on mitigation and adaptation with funding primarily from national sources.

Climate modelling is carried out at the National Hydraulic Research Institute of Malaysia (NAHRIM) and the School of Environmental and Natural Resource Sciences of the National University of Malaysia (Universiti Kebangsaan Malaysia, UKM) in collaboration with the Malaysian Meteorological Department (METMalaysia). UKM is leading the lower resolution Southeast Asia regional climate modelling collaboration among ASEAN countries through the SEACLID/CORDEX-SEA programme while NAHRIM leads the higher resolution climate modelling work for the country.

With the concentration of population into urban areas, assessment of changes in the urban climate through city-scale climate projections modelling becomes critical in strengthening the resilience of cities against the impacts of climate change. As a first step towards this end, UKM's Southeast Asia Disaster Prevention Research Initiative (SEADPRI-UKM) and the Atmosphere Ocean Group of the Department of Applied Mathematics and Theoretical Physics of the University of Cambridge implemented a Disaster Resilient Cities trial project centred on Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur.

Vulnerabilities of the country's long coastline of 8,840 km continue to gain attention as these regions are vital economic zones and population centres. Understanding the impacts of sea-level rise is crucial in assessing the vulnerability of the country's vast coastal regions. Through funding under the Eleventh Malaysia Plan, the National Hydraulic Research Institute of Malaysia (NAHRIM) has updated the sea-level rise projection and these results were used for vulnerability assessments presented in Chapter 4 of this report.

More recently, NAHRIM has also carried out an analysis of the sea surface temperature (SST) trend around the South China Sea and adjacent region based on the simple linear regression of the yearly averaged SST from 1982 to 2021. Most parts of water around Peninsular Malaysia recorded a warming trend of 0.1-0.15°C/decade, except over the southern peninsular where the warming rate is ~0.2°C/decade. The warming rate over Sarawak coastal water is 0.1-0.15°C/decade, whilst that over the Sabah coastal areas is slightly higher at 0.15-0.20°C/decade.

Under the 11th Malaysia Plan, NAHRIM has undertaken several studies through fine-scale modelling to produce projections of the impacts of climate change on the hydrological regime and water resources of Malaysia. Two primary studies had been completed namely the extension study of the Impact of Climate Change on the Hydrologic Regime and Water Resources of Malaysia (Phase 2) and the Impact of Climate Change on the Hydro-Climate of Malaysia based on IPCC AR5 for Peninsular Malaysia, Sabah and Sarawak. A third study focusing on drought was completed in 2022.

Research in the agriculture sector focuses on the vulnerabilities of key crops to the changing rainfall patterns, temperature rise and floodings. Studies were carried out to discover drought- and flood-tolerant traits of rice, rubber and cocoa.

Various studies were conducted on rice varieties that can be grown under drought conditions such as supplemental irrigation instead of the conventional maximum standing water in the field. Results showed that saturated water conditions did not cause significant reduction of the plant physiological performance. A local specialty rice variety had shown drought-tolerant traits that can be introduced to non-granary areas that are water stressed and the findings will be tested further through pilot scale studies under the 12th Malaysia Plan.

In the livestock sub-sector, research efforts were focusing on the development of country-specific enteric fermentation emission factor for the various cattle breed.

A long-term Free Air Carbon Dioxide Enrichment (FACE) study involved assessment of the impacts of elevated CO_2 on the productivity of lowland forest under Sustainable Forest Management practices is being carried out for the development of a potential adaptation measure for the forestry sector. Research in tropical peatland carried out by the Sarawak Tropical Peat Research Institute involved the use of chamber based (manual and automated chambers) and eddy covariance methods to measure GHGs fluxes.

Evidence from local research on climate change impacts to human health has increased considerably over the past few years as the Ministry of Health's bio-medical research wing, the Institute of Medical Research (IMR) has kept up with research on climate-related health threats. Health Research priorities under the 12th Malaysia Plan (2021–2025) has outlined two focus areas: climate change and climate-sensitive diseases; and health vulnerability and adaptation assessment including during extreme weather events. Research has focused on vector-borne, food and water-borne, Leptospirosis and non-communicable respiratory diseases as well as heat-related illnesses.

In the energy sector, the key research entities such as TNB Research (TNBR) and SIRIM has made some significant achievements in the deployment of renewable energy technologies particularly in the field of solar and biogas energy. SIRIM has developed a 200 MMBtu/day bio-compressed natural gas production plant in Tawau, Sabah to demonstrate the feasibility of utilisation of Compressed Bio-gas (CBG) from palm oil mill effluent for land transport and industry usage. Palm oil millers in Sabah have started to use compressed bio-methane gas in their trucks. Meanwhile, TNBR has developed a non-thermal plasma (NTP) system to reform biogas, adding value to its utilisation. Since NC3, TNBR has also continued its experiment and research on carbon capture and utilization (CCU) technologies at existing power plants. Two projects at the CCU Research Station in TNB Janamanjung power plant have yielded strong potential for adoption and scaling-up.

Systematic Observation

Systematic observation of climate change and assessment of its impacts are conducted by several frontline technical governmental agencies and departments.

Meteorological parameters are monitored by two key agencies, the METMalaysia which gathers meteorological data from its nationwide network of weather stations while the Department of Irrigation and Drainage (DID) collects rainfall data and monitor water level of river basins for its hydrological observation.

Other agencies such as the Slope Engineering Division of Public Work Department (PWD) and Projek Lebuhraya Utara-Selatan (PLUS), the concessionaire of the north-south axis highway of Peninsular Malaysia also carried out rainfall observations at hilly region and along the tolled highways respectively. Sea level rise is monitored by the Department of Survey and Mapping Malaysia (JUPEM) which operates 21 tide gauge stations. With the recorded tidal data, JUPEM is able to obtain sea level rise trend through time series analysis from the date of establishment of the tide gauge station.

Monitoring in the biodiversity and natural ecosystem are reported through the national reporting to the Convention on Biological Diversity and the Forest Resources Assessment of the United Nations Food and Agriculture Organisation which focuses on the baseline status and trends. The assessments contained in these reports have indirect information on climate change impacts.

The Ministry of Health (MOH) has implemented a number of programmes and activities to monitor certain communicable and environmental diseases that are directly or indirectly related to climate change. To improve population health in a changing climate, the resilient healthcare system includes a climate-sensitive disease surveillance system as well as capacity building of health personnel to enhance their response and readiness capabilities to the health impacts of climate change.

Air quality is monitored by the Department of Environment (DOE) of the federal ministry and the Natural Resources and Environment Board (NREB) under the Sarawak Government via 65 automatic and 14 manual stations installed throughout the country.

6. Capacity-building, Education, Public Awareness, Information-sharing and Networking

Interest and attention on climate change continue to grow within the government, research institutions, private sector, civil society organisations and general public since NC3.

At the policy-making level, the government has enhanced its focus on addressing climate change as illustrated through continuous mainstreaming of mitigation and adaptation elements into the relevant development policies. The financial and capital sector over the past few years has taken a keen interest on climate change and had carried out a series of awareness programme among its members from regulatory body to private banks and institutional investors.

Civil society organisations with their varied and specific expertise continue to play an active role in increasing the overall awareness and responses of Malaysia in facing the climate change phenomena. Following the adoption of the Paris Agreement and the spate of climate-related disasters around the world, local media interests were heightened on the importance of international cooperation to address climate change.

Capacity Building

Malaysia continues to build its institutional capacity in applying the IPCC 2006 Guidelines in the preparation of its GHG Inventory, enabled by regional and local trainings especially in the energy, IPPU, AFOLU and waste sectors. These efforts were made possible through the UNFCCC's workshops and the annual Workshop on Greenhouse Gas Inventories in Asia (WGIA), an initiative of Japan via its National Institute of Environmental Studies (NIES).

TNBR conducted training with the aim to develop the CO_2 and non-CO_2 emission factors by flue gas for the electricity sub-sector while personnel from the Malaysian Agriculture Research and Development Institute (MARDI) were trained on the procedures for higher tier estimation of GHG emissions from livestock.

Key agencies implementing mitigation-related efforts are building on their existing training programmes to enhance the capacity of their personnel to ensure the continuity and successful outcomes of those efforts.

In the promotion of renewable energy, the Sustainable Energy Development Authority (SEDA) and TNBR had continued with their respective human capital development training programmes in the area of both grid-connected and off-grid photovoltaic system design, installation and maintenance courses. SEDA has also engaged the Malaysian Photovoltaic Industry Association in terms of regulatory knowledge, policy direction, technology development and business outlook.

In support of the National Energy Efficiency Action Plan (2016-2025), courses on energy audits and energy management continue to be conducted by both SEDA and TNBR. In the last four years since NC3, these courses had trained hundreds of energy managers and professionals in measurement and verification from more than a hundred organisations.

Meanwhile, in the construction industry, the Construction Industry Development Board (CIDB) has also continued to produce certified facilitators and assessors through its Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) programme. This programme helps in the design, construction and operation of energy efficient buildings.

For the forestry sector, capacity and awareness of various stakeholders for the implementation of the National REDD plus Strategy were enhanced particularly at the sub-national level with technical support from national agency. In addition, Sabah Forestry Department also conducted capacity-building activities to implement its REDD plus strategy. Forestry departments have enhanced their preparedness for climate impacts by incorporating forest fire management into their respective forest management protocols.

In the area of vulnerability assessment and adapting to climate change, the NAHRIM has carried out several capacity building programmes in regional climate change modelling for Malaysia as well as vulnerability and adaptation (V&A) assessment for the targeted groups of relevant stakeholders. Specific capacity building programmes to strengthen the expertise of officers in assessment of climate vulnerabilities included the areas of water resources, sea level rise, sea surface temperature and saltwater intrusion. For the water sector, NAHRIM has produced the Climate Change Adaptation Framework which provides strategic planning options to address adverse impacts of climate change and increase sectoral resilience. It has also embarked on V&A training through the development of Malaysia Adaptation Index (MAIN), which summarises the level of vulnerability and readiness of each state in facing the impacts of climate change.

Workshops and training to strengthen linkages between disaster risk reduction and climate change was led by Universiti Kebangsaan Malaysia's Southeast Asia Disaster Prevention Initiative (SEADPRI-UKM) in collaboration with multiple partners under the aegis of the National Disaster Management Agency (NADMA) Malaysia.

In anticipation of adverse climate impacts on food production, agriculture researchers and officers participated in various training programmes to equip themselves with available tools, skills and knowledge. Researchers were exposed to various climate resilience technologies and practices through capacity-building programmes by international bodies for ASEAN member states. MARDI is also spearheading rice genetic research and cooperation with other rice-producing ASEAN members as a climate resilience solution for this staple food.

Attention is also being paid to developing resilience of vital infrastructures such as in the oil and gas fields, electricity generation assets and public health facilities.

Education

Climate change education saw increased interests within the public sector in the past few years. Public agencies on the frontline of climate impacts are equipping their personnels with climate change knowledge and incorporating mitigation and adaptation elements in their programmes and plans.

Meanwhile, dissemination of information and knowledge on climate change continues in both formal and informal environmental education through the schools' and higher education institutions' curriculum and extra-curriculum activities. The Ministry of Education has incorporated climate change in the geography syllabus of secondary schools as well as in language and science subjects. To enhance the research capacity and output of academicians, the Academy of Science Malaysia (ASM) held seminars and workshops centred on the IPCC Fifth Assessment Report and played a role in linking local scientists' engagement with the IPCC's process.

State-owned enterprises and major conglomerates are acutely aware that they need to beef up awareness internally and lead by example by holding regular lectures and trainings to sensitise their respective personnel. The corporate sector has also stepped up its informal environmental education in tandem with the increase in Corporate Social Responsibilities programmes among the private sector.

Public Awareness

Awareness on climate change among general public is best strengthened by direct participation of the targeted communities. Towards this end, there is a marked increase of awareness programmes involving direct participation in the area of forestry, energy, waste and sea level rise. Civil society organisations in Malaysia also played their parts in raising awareness of climate change via their respective programmes with recurring annual events or long-standing engagement with local communities.

In terms of climate-related disaster preparedness and development of early warning system, the DID provides information on floods, rainfall, river water level and associated flood risks, flood cameras, drought by river flow and drought by dam to the public through a web portal. For communities at the frontline of vulnerable infrastructure such as dams, TNBR has embarked on a programme to sensitise local communities including indigenous villagers living close to hydro power stations operated by its parent company TNB. The programme includes evacuation drills involving hundreds of residents and villagers.

In more recent time, the financial and capital market sector has embarked on a series of awareness raising campaign to educate bankers, institutional investors and insurers on the importance of adopting sustainability in their operation and greening their investments portfolios. In its series of Thematic Sustainability Workshop, Bursa Malaysia Berhad (formerly known as the Kuala Lumpur Stock Exchange) has raised awareness on exposure to climate risks and the role of the financial sector towards the transition to a low carbon economy.

Information-sharing and Networking

Collaboration to address the challenges of climate change has continued at the international and regional level. Malaysia's networking in climate actions cover the areas of energy, industrial processes, agriculture, low carbon cities.

At the UNFCCC, UNDP and GCF level, Malaysian's policy-makers were able to build their capacities in key areas of climate actions such as climate finance, adaptation, REDD plus implementation, development of nationally-determined contributions and enhanced transparency framework. The latter two areas are vital aspects towards implementation of the Paris Agreement which gained momentum after it came into force in November, 2016.

At the ASEAN level, the country has been in active collaboration with the ASEAN Centre for Energy in the area of energy management. Malaysian companies were keen supporters of the ASEAN Energy Awards (AEA) initiative that was launched in 2000 to promote awareness on best practices in energy efficiency and conservation in buildings, industries and energy management, renewable energy, and clean coal technology.

7. Constraints, Gaps, Level of Support Received and Needs

Malaysia has utilised domestic resources as well as financial, technical and capacity building support from international sources to implement climate actions. Both multilateral and bilateral resources were received by federal and state agencies.

Constraints and Gaps

Challenges remained in implementing the country's commitment to address climate change and its impacts. Some of the challenges had been identified by the Team of Technical Experts (TTE) during the International Consultation and Analysis of Malaysia's Third BUR. These challenges include the development of country-specific emission factors, improvement of activity data collection, long term modelling tools for emission projection and enhancing the national capacity to conduct the technology needs assessment. More importantly is the availability of the right type of technology for mitigation and adaptation implementation and the availability of funding for the implementation.

Level of Support Received

The main source of international financial support is through the Global Environmental Facility (GEF), one of the two operating entities of the UNFCCC's financial mechanism from cycle 1 to 7 (June 1994 to June 2022), The funding provided by GEF, other multilateral agencies and bilateral sources were channeled through specific projects.

Financial support through GEF-6 and GEF-7 cycles were primarily used to build up technical and technological capacities in transport, energy, forestry (including peatland), low carbon cities and community empowerment projects.

The amount of funding provided by GEF for NC4 is USD500,000. It should be noted that in the preparation of BUR4 which was submitted to the UNFCCC on 31 December 2022, the allocation of USD352,000 from GEF for BUR3 was used. This was made possible as the balance from BUR2's allocation was used to prepare BUR3 which was submitted on 31 December 2020.

The other UNFCCC's financial mechanism operating entities, the Green Climate Fund (GCF) has provided readiness support for Malaysia to enhance its implementation framework to access results-based payment for the forestry sector. Malaysia is also in the process of applying for financial support to develop a comprehensive National Adaptation Plan.

Besides financial support, Malaysia has participated in a wide range of capacity building programmes in the areas of GHG inventory, mitigation (measurement, reporting and verifying emissions data), adaptation planning, implementing and enhancing NDCs, climate negotiations, climate finance and Article 6 and 13 of the Paris Agreement provided by various multilateral organisations, Annex I and non-Annex I Parties to the UNFCCC.

At the sub-national level, the states of Johor and Melaka have received capacity-building from the United Kingdom Prosperity Fund's Future Cities Programme and the Japanese Joint Crediting Mechanism's City to City Collaboration for Building Energy Monitoring and Reporting System.

Needs

Malaysia is only beginning to report on its achievement of its NDCs and additional technical capacity-building and financial assistance would be needed to develop systems to track NDCs implementation and cooperative approaches (Article 6 of the Paris Agreement).

An estimated amount of USD2.25mil in international funding is required for GHG inventory improvement. To implement the identified mitigation actions, major financial support is required by the iron and steel industry to the tune of USD47mil. For adaptation, a preliminary estimate of USD63.6mil is required for various initiatives to enhance resilience measures throughout the country.

CHAPTER 1

1. NATIONAL CIRCUMSTANCES

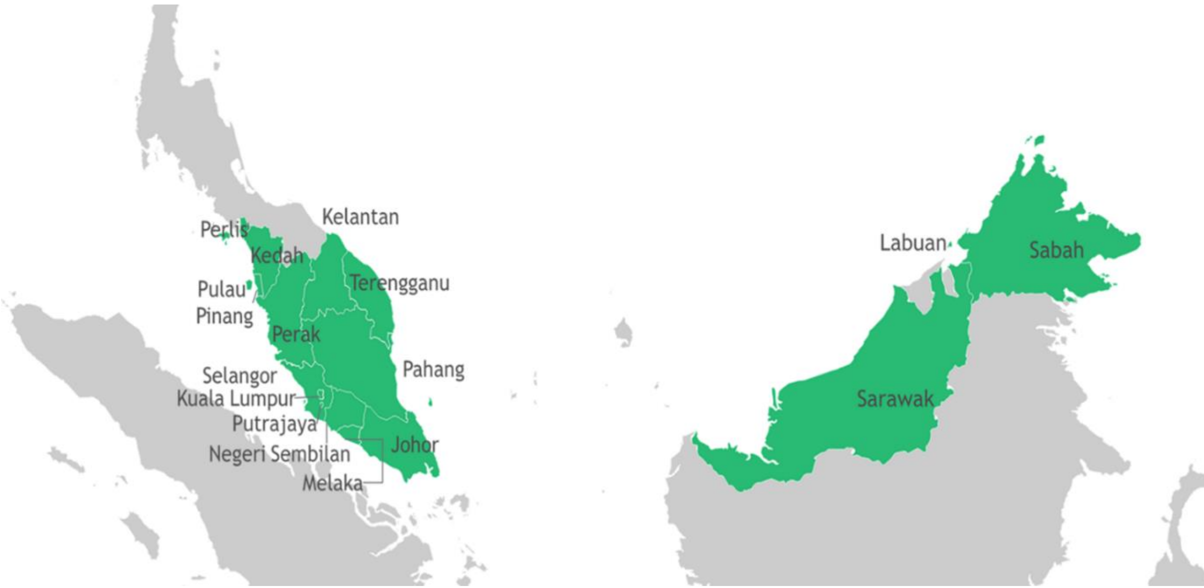
1.1 Introduction

This chapter provides information on Malaysia's national circumstances up to the year 2019 where relevant geography, natural resources, social and economic published statistics are available. It also communicates the status of key climate-related sectors and their respective policies and strategic measures.

1.2 Geography: Location and Topography

Malaysia lies between 0º 51' N and 7º 33' N, and 98º 01' E and 119º 30' E and is located in the Southeast Asia region. It has a land area of 330,241 km^2 with about 4,809 km of coastline and over 879 islands. It consists of thirteen states and three Federal Territories. Eleven of the states and two of the Federal Territories (Kuala Lumpur and Putrajaya) are located in Peninsular Malaysia (Figure 1.1). The states of Sabah and Sarawak are located on the Borneo Island and are separated from Peninsular Malaysia by the South China Sea. The Federal Territory of Labuan with an area of 92 km^2 and with 81.5 km coastline is located off the coast of western Sabah.

Figure 1.1: Map of Malaysia



The topography of Peninsular Malaysia ranges from coastal plains to mountainous terrains. It has a land area of approximately 132,078 km^2 and a coast length of about 3,771.5/1,972 km. Its north-south extent is about 746 km and its maximum east-west width is about 315 km. It is also divided into the east and west coasts by the central mountainous region known as the Titiwangsa Range which extends from north to south for about 617 km in length with the highest point reaching 2,183 m above sea level. It is also the headwater of the Pahang River, which at 482 km is the longest river in Peninsular Malaysia and the third longest river in Malaysia.

Sabah which lies on the north-eastern part of Borneo Island has a land area of approximately 73,621 km^2. Its coastline runs the length of approximately 1,035 km. Sabah's topography is primarily mountainous, especially in the western flank with undulating lowland basins in the eastern part. The Crocker Range divides the western coastal plains from the hinterland of Sabah. At 4,095 m above sea level, Low's Peak on the Kinabalu plateau of the Crocker Range is the highest point in Malaysia. The Kinabatangan River is the longest river in Sabah at 568 km and is the second longest in Malaysia.

Sarawak has a land area of approximately 124,450 km^2 and lies on the north central and western part of Borneo Island. Sarawak's coastline is about 1,802 km. Its topography features coastal plains followed by a narrow belt of hills before sharply rising into a mountainous region towards the Kalimantan border with Indonesia. Mount Murud at 2,422 m is the highest mountain in Sarawak. The second highest peak Mount Mulu (2,377 m) has the largest natural limestone cave system in the world. The Rajang River at 780 km is the longest river in Sarawak as well as in Malaysia.

1.3 Governance and Climate Change

Malaysia is a federation consisting of 13 states and 3 federal territories. The Head of State is the Yang Di-Pertuan Agong (also known as the King), and is elected among the nine monarchical states for a five-year term. The head of states for the states of Kedah, Perak, Selangor, Johor, Pahang, Terengganu and Kelantan their respective sultans, while the head of states of Negeri Sembilan and Perlis are the Yang Di-Pertuan Besar and Raja respectively. The head of states of the other four states, namely Pulau Pinang, Melaka, Sarawak and Sabah are called Yang Di-Pertuan Negeri or sometimes referred to as Governor. They are elected by Yang Di-Pertuan Agong for a renewable four-year term, on the advice of the Prime Minister and in consultation with the states government.

Its legislative power is divided between its federal and state legislatures. The Malaysian Parliament consist of the Dewan Negara (Senate) with 70 members and the Dewan Rakyat (House of Representatives) with 222 members. Out of the 70 senators in the Senate, 44 are appointed by His Majesty Yang Di-Pertuan Agong while 26 are elected by the State legislatures. The 222 members of the Dewan Rakyat are elected in a general election, due every 5 years. The Prime Minister is the Head of Government and must be a member of the House of Representative that have the support of the majority of the members of House of Representative.

At the state level, the state legislative assemblies are also elected in every five years. The head of government for each of the nine monarchical states is the Menteri Besar, and the four remaining states is the Chief Minister.

The federal legislature and the executive arm of the government have the responsibility for developing and implementing policies and drafting national laws to enable the country to fulfil its international obligations in addressing climate change.

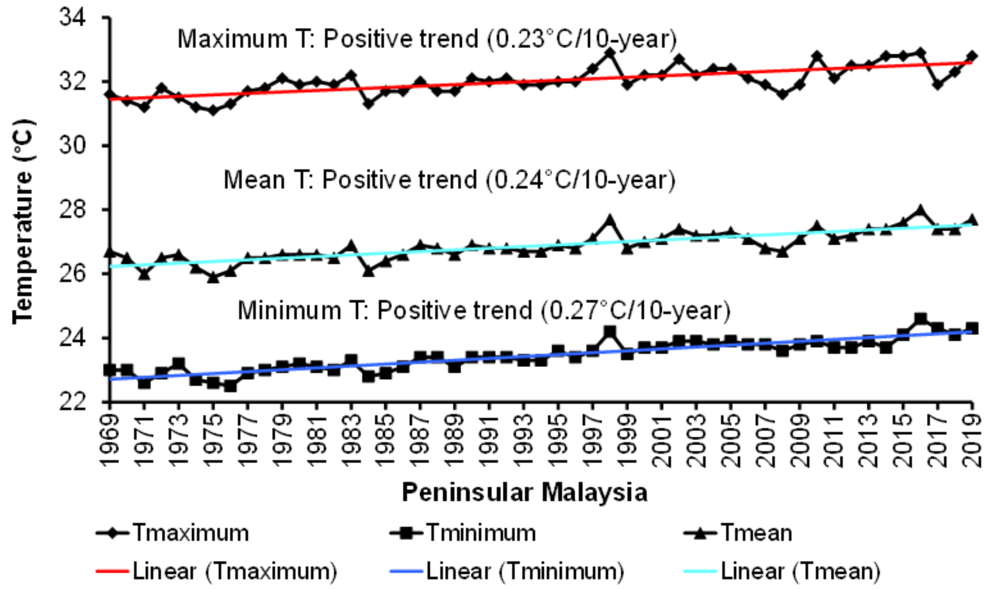
The Ministry of Natural Resources and Environmental Sustainability (NRES) is the focal ministry for climate change. Nevertheless, the respective states have jurisdiction over the management of natural resources, especially land, forest and water.

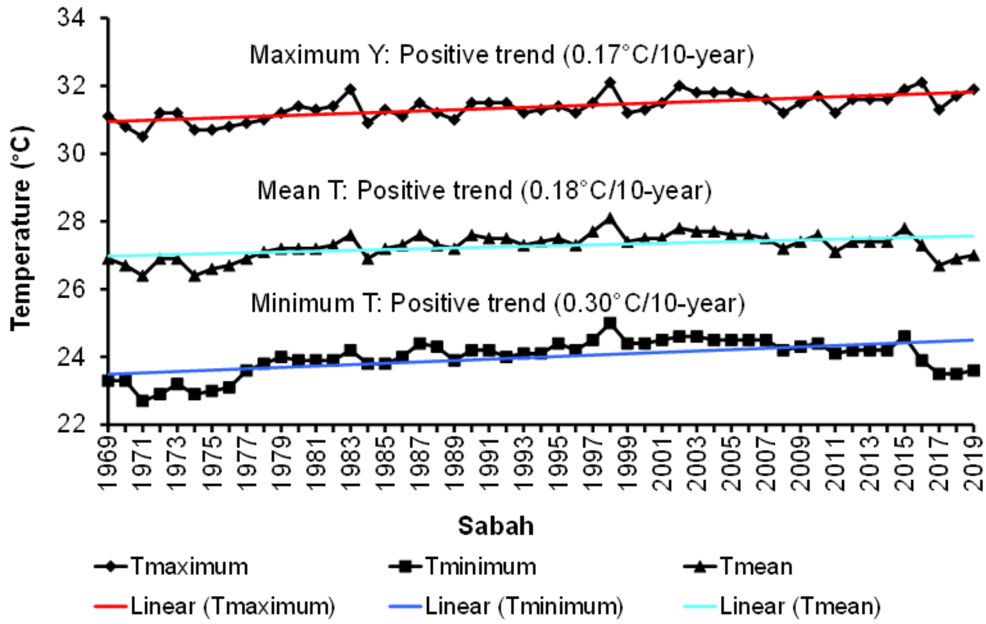
1.4 Climate

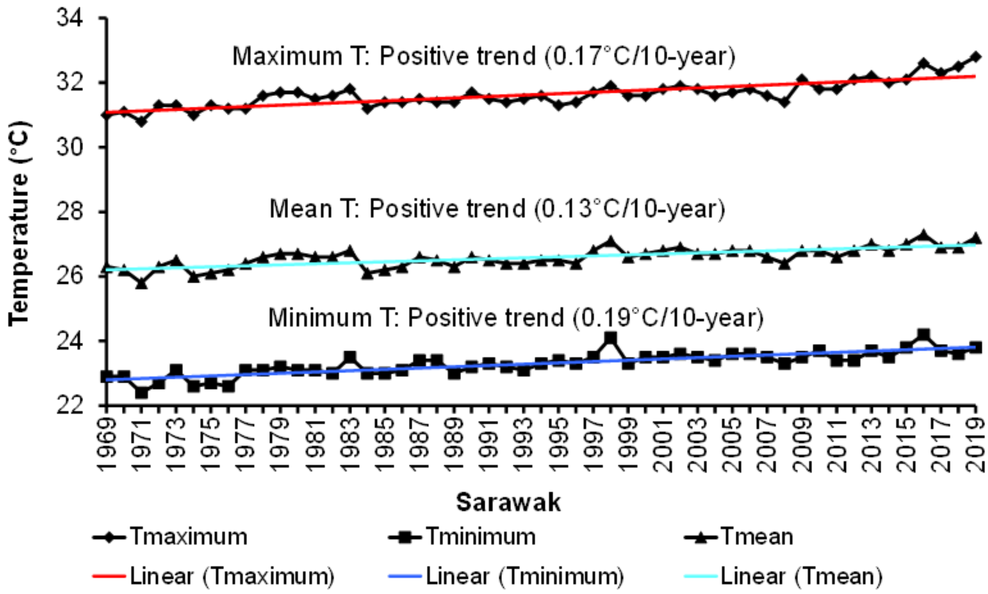
1.4.1 Annual Temperature Trends for Malaysia

Malaysia has an equatorial climate with a uniform daily variation of temperatures throughout the year. The daily mean temperature lies between 26 ºC and 28 ºC. In the past 50 years, there has been a positive trend in temperature increase. Figure 1.2 shows the annual trends of temperature for Peninsular Malaysia, Sarawak and Sabah from 1969 to 2019 respectively. The surface mean temperature increased by 0.13 ºC to 0.24 ºC per decade. The surface maximum temperature increased by 0.17 ºC to 0.23 ºC per decade while minimum temperature increased by 0.19 ºC to 0.30 ºC per decade.

Figure 1.2: Annual Temperature Trend: Peninsular Malaysia, Sabah and Sarawak



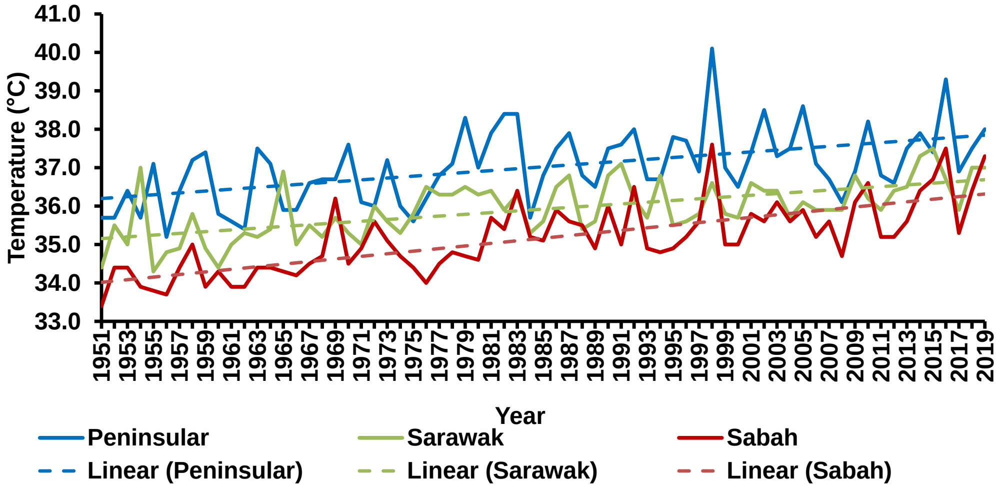




Source: Malaysian Meteorological Department

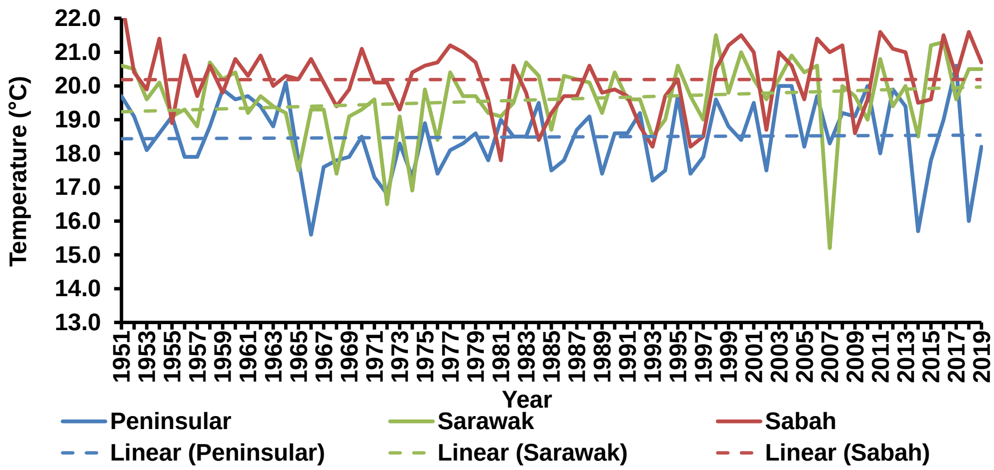
The highest daily maximum and lowest daily minimum temperatures for each year from 1951 to 2019 according to data collected from 19 meteorological stations across Malaysia are shown below in Figure 1.3 and Figure 1.4. The highest daily maximum temperature shows an increasing trend with the highest daily maximum temperature over in Peninsular Malaysia, followed by Sarawak and Sabah. However, the lowest daily maximum shows a different trend. Sarawak records an increasing linear trend while Peninsular and Sabah records nearly zero linear trend.

Figure 1.3: Highest Daily Maximum Temperature for Peninsular Malaysia, Sabah and Sarawak



Source: Malaysian Meteorological Department

Figure 1.4: Lowest Daily Minimum Temperature for Peninsular Malaysia, Sabah and Sarawak



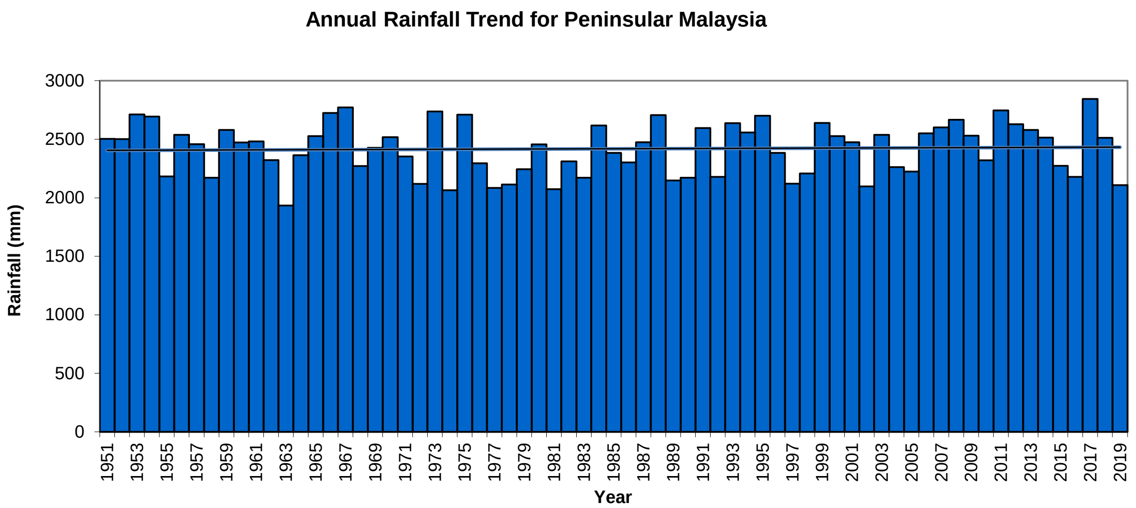
Source: Malaysian Meteorological Department

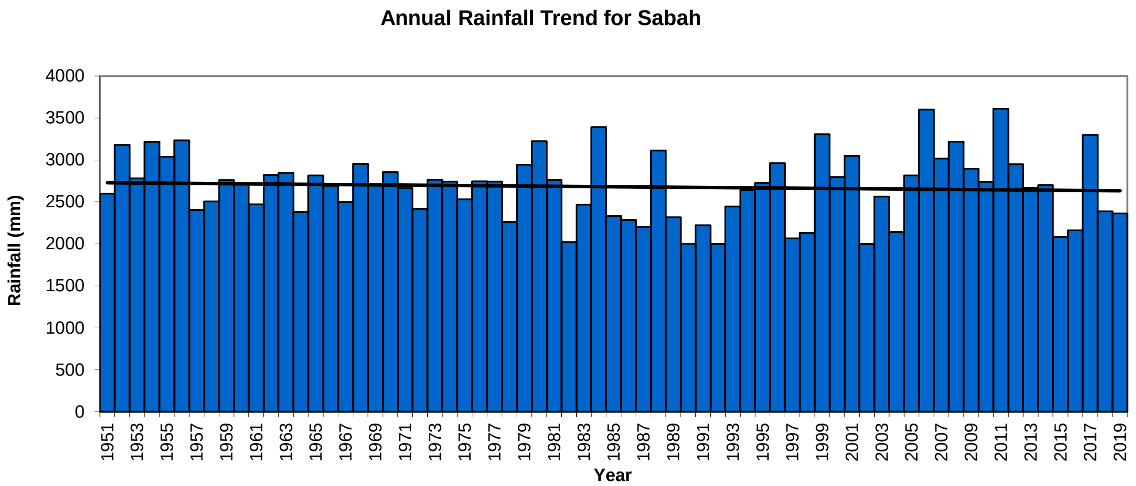
The winds over the country are generally light and variable. However, there are some uniform changes in the wind flow patterns characterised by two monsoons which are separated by two shorter inter-monsoon periods. North-eastern winds are strong during the boreal winter monsoon which usually occurs from November to March. The boreal summer monsoon occurs between May to September with south-westerly winds prevailing during this period. During inter-monsoonal periods, occurrence of heavy rain and thunderstorms in the late afternoons and evenings are relatively common.

1.4.2 Annual Rainfall Distribution

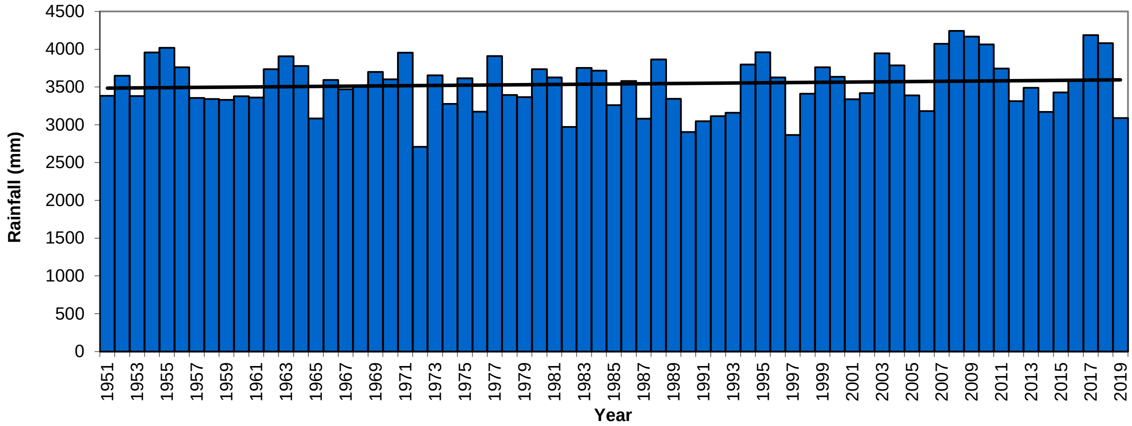
Rainfall distribution in Malaysia is influenced by topography and monsoon winds. As a result, Malaysia has abundant annual rainfall that averages about 2,000 mm to 4,000 mm. During the northeast monsoon, the east coast of Peninsular Malaysia, northeast of Sabah and southern Sarawak can sometimes experience spells of heavy rain lasting about three days, which can cause severe floods. In contrast, the southwest monsoon is drier with lower rainfall. During the inter-monsoon periods, heavy rain from convective showers and thunderstorms occurs in the late afternoons and evenings. Figure 1.5 shows the annual rainfall for Peninsular Malaysia, Sabah and Sarawak from 1951 to 2019. For this period, there is very slight increasing trend in the rainfall for Peninsular Malaysia and Sarawak whereas a slight decreasing trend in Sabah. The drier years are mainly because of strong El Niño and the Indian Ocean Dipole events.

Figure 1.5: Annual Rainfall Trend in Peninsular Malaysia, Sabah and Sarawak





Annual Rainfall Trend for Sarawak



Source: Malaysian Meteorological Department

Malaysia receives about 6 hours of direct sunlight per day and cloud cover cut-off substantial amount of direct sunlight particularly in the afternoon and evening.

1.5 Sea Level Rise

Malaysia’s coastal areas lie within four seas, namely the Straits of Malacca, the South China Sea the Sulu Sea and Celebes Sea. Changes in sea level in these seas would affect the coastal landmass of the country. Sea level rise and its trend is being monitored through 21 tide gauge stations since 1981 by the Department of Survey and Mapping Malaysia (JUPEM). Table 1.1 shows the trend across 11 stations in Peninsular Malaysia and Table 1.2 shows the trend across 8 stations in Sabah, Sarawak and the Federal Territories of Labuan. Data from two new stations installed in 2020, namely at Tanjung Pengelih (Peninsular Malaysia) and Santubong (Sarawak) would be made available after the first five-year observation period. Between 1986 and 2021, the average annual sea level rise for Peninsular Malaysia was 3.2 mm per annum. For Sabah and Sarawak and the Federal Territories of Labuan, sea level rise was 2.9 mm per annum from 1988 to 2021.

Table 1.1: Sea Level Rise Peninsular Malaysia

Tide Gauge Station Location	Data Duration	Average Annual MSL (m)	Sea Level Rise (mm/yr)
Pulau Langkawi	1986 – 2021	2.234	2.3
Pulau Pinang	1985 – 2021	2.706	2.8
Lumut	1985 – 2021	2.211	2.0
Pelabuhan Klang	1984 – 2021	3.658	2.7
Tg. Keling	1985 – 2021	2.871	2.4
Kukup	1986 – 2021	4.034	3.8
Tg. Sedili	1987 – 2021	2.428	2.8
Pulau Tioman	1986 – 2021	2.857	3.6
Tg. Gelang	1984 – 2021	2.832	4.1
Cendering	1985 – 2021	2.242	5.4
Geting	1987 – 2021	2.314	3.1
Average Annual Sea Level Rise for Peninsular Malaysia			**3.2 mm**

Table 1.2: Sea Level Rise Sabah, Sarawak and Federal Territories of Labuan

Tide Gauge Station Location	Data Duration	Average Annual MSL (m)	Sea Level Rise (mm/yr)
Bintulu	1993 – 2021	1.923	3.2
Miri	2006 - 2021	2.093	0.4
Kota Kinabalu	1988 – 2021	2.534	3.1
Kudat	1996 – 2021	2.636	4.8
Sandakan	1994 – 2021	2.752	2.9
Lahad Datu	1996 – 2021	2.850	2.0
Tawau	1988 – 2021	2.723	3.0
Labuan	1996 – 2021	2.962	4.0
Average Annual Sea Level Rise (Sabah, Sarawak & Labuan)			**2.9 mm**

Source: Department of Survey and Mapping Malaysia

1.6 Forest and Biodiversity

1.6.1 Forests

Malaysia's forests are comprised of complex ecosystems and are home to a wide range of species. Malaysia has consistently maintained more than 50% of its landmass as forest following its voluntary pledge at the Earth Summit in 1992. This includes Permanent Reserved Forests (PRFs), state land forests (SLF) and Totally Protected Areas (TPA/PA). In 2019, 18.14 million ha, or approximately 54.9% of the total land area of Malaysia was under forest cover. The remaining land area comprised of agricultural and commodity crops, settlements, wetlands and grasslands. Table 1.3 below presents a breakdown of the total forested areas in Malaysia according to the three regions.

Table 1.3: Total Forested Areas

	Forested area (million ha)			
Year	**Peninsular Malaysia**	**Sabah**	**Sarawak**	**Total**
2005	5.83	4.36	7.62	17.82
2015	5.79	4.56	8.05	18.39
2016	5.77	4.56	7.91	18.24
2017	5.77	4.77	7.80	18.34
2018	5.76	4.77	7.75	18.27
2019	5.73	4.68	7.72	18.14

Source: Ministry of Natural Resources, Environment and Climate Change

1.7 Biodiversity

Malaysia is considered as one of the world mega-diverse countries. The richness in biodiversity in terms of estimated species in the respective flora and fauna groups is shown in Table 1.4.

Table 1.4: Summary of Malaysia's Overall Biodiversity Richness

Group	Estimated Species
Mammals	306
Birds	742
Reptiles	567
Amphibians	242
Marine Fishes	1,619
Freshwater Fishes	449
Invertebrates	150,000
Vascular Plants	15,000
Fungi	>4,000
Mosses	522
Hard corals	612

Source: Sixth National Report (of Malaysia) to the Convention on Biological Diversity

Malaysia's terrestrial biodiversity is concentrated within tropical rainforests that extend from coastal plains to mountainous areas, including wetlands, such as lakes and rivers. Marine biodiversity is primarily located among islands and coastal ecosystems, especially in mangrove/tidal mudflats, coral reefs and seagrass meadows. Agricultural biodiversity is conserved in plantations, rice fields, fruit orchards, and farms. Table 1.4 below presents a general overview of different ecosystems across Malaysia.

Table 1.4: Overview of Ecosystems

Thematic Area	Ecosystem
Forest Biodiversity	• Lowland dipterocarp forest • Heath forest • Limestone forest • Mixed dipterocarp forest • Hill dipterocarp forest • Hill mixed dipterocarp forest
Mountain Biodiversity	• Montane forest • Subalpine forest
Inland Waters Biodiversity	• Peat swamp forest • Freshwater swamp forest • Riparian forest • Rivers, ponds, lakes
Marine and Coastal Biodiversity	• Coastal hill dipterocarp forest • Mangrove forests • Mudflats • Coral reef • Sea grass
Agricultural Biodiversity	• Plantations • Rice fields • Fruit orchards and vegetable farms • Livestock rearing and aquaculture farms

Source: Sixth National Report (of Malaysia) to the Convention on Biological Diversity

1.8 Water Resources

Malaysia relies on rainfall as its main water source that feeds its 2,986 river basins of which 189 are major ones and to recharge its groundwater reservoirs. The country receives about 973 billion cm^3 of water from rainfall annually according to the National Water Resources Study (2000-2050) report. From this, the total surface runoff is estimated to be 496 billion cm^3 per year. On a yearly basis, about 414 billion cm^3 return to the atmosphere through evapotranspiration process and 63 billion cm^3 as groundwater recharge.

Rainfall is unevenly distributed with some states receiving more rain than others. High intensity and prolonged periods of rainfall results in flooding in low-lying and coastal areas where rivers are short and catchment areas are small. Certain regions with smaller water catchments are likely to be more susceptible to water stress in the future.

The National Water Resources Policy launched in 2012 under the 10th Malaysia Plan outlined clear directions and strategies for water resources management, including collaborative governance to ensure water security and sustainability. The 11th Malaysia Plan continued the policy direction and emphasised that stronger protection and conservation of water resources needs to be carried out. Alternative water supply initiatives such as rainwater harvesting, tube wells and gravity feed systems are being implemented as supplementary sources to serve remote areas.

1.9 National Physical Planning

For the period until 2020, national physical development in Peninsular Malaysia is guided by three physical planning documents, the National Physical Plan-3 (NPP-3), the Second National Urbanisation Policy (NUP-2) and the National Rural Physical Plan 2030 (NRPP 2030). Due to constitutional arrangements, the states of Sabah and Sarawak have autonomy in the development control process and are governed by separate planning systems. Thus, NPP-3, NUP-2 and NRPP 2030 only applies to Peninsular Malaysia.

The NPP-3 is the highest-ranking planning document in the national development framework which translates strategic and sectoral policies into spatial and physical dimensions. Emphasis is placed on sustainability and resilience towards climate change in three strategic directions:

a) Sustainable management of natural, food and heritage resources;
b) Holistic land use planning; and
c) Low carbon cities and sustainable infrastructure.

The three strategic directions are being implemented through 15 strategies and 44 actions. The 15 strategies are:

a) Improving preservation and conservation of national ecological assets;
b) Managing and controlling development in environmentally sensitive areas;
c) Enhancing security and sustainability of water resources;
d) Managing mineral resource exploration;
e) Promoting food security;
f) Strengthening protection and preservation of national archaeological and natural heritage sites;
g) Optimising land use and availability;
h) Managing natural disaster risk areas;
i) Managing development growth and sprawl;
j) Promoting integrated rural development;
k) Creating low carbon cities development;
l) Promoting use of sustainable energy sources;
m) Implementing integrated water cycle management;
n) Promoting green mobility; and
o) Strengthening integrated and sustainable solid waste management.

The NUP-2 provides guidance on sustainable urban planning and development with an emphasis for balanced development physically, environmentally, socially and economically. The NRPP 2030 is the first spatial rural development document that outlines policy statements, strategies and implementation measures towards materialising the rural development vision.

1.10 Population

1.10.1 Population and Population Density

The total population of Malaysia in 2019 was 32.5 million. Malaysia's population has been growing quite steadily in the past 15 years. The population density of the country registered an increase from 79 persons per km^2 in 2005 to 99 persons per km^2 in 2019. Table 1.5 provides a summary of Malaysia's population and population density since 2005.

Table 1.5: Population and Population Density

Year	Population (million)	Population Density (population/km^2)
2005	26.0	79
2015	31.2	94
2016	31.6	96
2017	32.0	97
2018	32.4	98
2019	32.5	99

Source: Department of Statistics Malaysia

1.10.2 Urbanisation

The national urbanisation rate grew from 51.4% in 1990 to 76.2% in 2019. Table 1.6 provides a summary of Malaysia's urbanisation rate by state.

Table 1.6: Urbanisation Rate by State

State	Urbanisation Rate (%)									
	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Johor	50.1	56.2	64.8	68.4	71.8	75.6	77.1	77.7	78.3	78.9
Kedah	32.9	35.6	39.1	51.4	64.7	68.0	68.6	70.9	71.6	72.3
Kelantan	33.0	33.5	33.5	37.8	42.3	47.0	47.9	48.7	49.7	50.6
Melaka	38.8	51.0	67.5	77.3	86.4	91.9	92.7	93.4	94.0	94.6
Negeri Sembilan	42.9	47.9	54.9	60.4	66.4	72.0	73.0	73.3	73.6	74.4
Pahang	31.5	35.5	42.0	46.2	50.4	55.1	56.0	56.0	56.9	57.9
Perak	53.9	56.1	59.0	64.3	69.7	74.4	75.3	75.4	75.5	75.8
Perlis	26.5	29.7	34.0	42.3	51.1	59.9	61.5	61.7	63.0	64.3
Pulau Pinang	75.2	77.3	79.7	85.2	90.9	93.9	94.4	94.6	95.0	95.3
Sabah	33.5	38.8	48.1	51.2	54.3	57.9	58.2	58.8	59.5	60.3
Sarawak	37.9	42.4	48.1	51.0	53.8	57.1	57.8	57.8	58.5	59.2
Selangor	75.9	82.1	87.7	89.7	91.3	93.0	93.3	93.3	93.3	93.4

State	Urbanisation Rate (%)									
	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Terengganu	44.1	46.3	49.4	54.0	59.1	63.4	64.3	65.0	65.7	66.4
Federal Territory of Kuala Lumpur	100	100	100	100	100	100	100	100	100	100
Federal Territory of Labuan	-	64.2	76.3	79.5	82.9	84.5	84.7	84.8	84.9	83.7
Federal Territory of Putrajaya	-	-	-	-	100	100	100	100	100	100
Malaysia	51.4	56.0	62.0	66.5	71.0	74.3	74.8	75.2	75.6	76.2

Source: Department of Statistics Malaysia

1.10.3 Age Distribution

In 2019, 23.5% of the population was under 15 years old, 69.8% were between the ages of 15 and 64, and a smaller percentage of 6.7% were over 65 years old. Table 1.7 highlights the changing composition of ages within the Malaysian population.

Table 1.7: Population by Age Group

Year	Less than 15 years (%)	15 to 64 years (%)	65 years and above (%)
2005	30.9	64.6	4.4
2015	24.9	69.2	5.9
2016	24.5	69.5	6.0
2017	24.1	69.6	6.3
2018	23.8	69.7	6.5
2019	23.5	69.8	6.7

Source: Department of Statistics Malaysia

1.10.4 Life Expectancy

The average life expectancy at birth has increased marginally from 73.6 years in 2005 to 74.8 years in 2019. Female life expectancy has increased to 77.4 years in 2019 from 76.0 years in 2005 while male life expectancy increased marginally from 71.4 years in 2005 to 72.5 years in 2019. Table 1.8 shows a summary of the change in life expectancy at birth.

Table 1.8: Summary of Average Life Expectancy at Birth

Year	Female	Male	Overall
2005	76.0	71.4	73.6
2015	77.1	72.5	74.6
2016	77.0	72.1	74.4
2017	77.1	72.1	74.4
2018	77.2	72.3	74.6
2019	77.4	72.5	74.8

Source: Department of Statistics Malaysia

Health and wellbeing of the people are an essential part of an improved standard of living that Malaysia strives to achieve. In the mid-term review of the 11th Malaysia Plan (2016-2020), the Malaysian government set the goal of creating a sustainable healthcare system and the first step it took in that direction was with the introduction of the Malaysia National Health Policy (MNHP). This policy focuses on population health as well as the sustainability of the healthcare system.

The Ministry of Health (MOH) is the main provider of healthcare services. An extensive network of primary healthcare services is delivered by Government health facilities together with private medical and dental clinics. This network is supported by secondary and tertiary services provided by both the Government and private sector. Table 1.9 presents a summary of the healthcare facilities in the country for 2011, 2015, 2017 and 2019.

Table 1.9: Summary of Healthcare Facilities

Year	2011		2015		2017		2019	
	Number	Beds (Official)	Number	Beds (Official)	Number	Beds (Official)	Number	Beds (Official)
Primary Healthcare Facilities – Ministry of Health								
Health Clinics [a]	985	-	1,061	-	1,085	-	1,114	-
Rural Clinics	1,864	-	1,808	-	1,796	-	1,771	-
Mobile Health Clinics (Teams)	184	-	203	-	217	-	230	-
Flying Doctor Services	5 [b]	12 [c]	6 [b]	12 [c]	6 [b]	12 [c]	5 [b]	11 [c]
Standalone Dental Clinics	51	459 [d]	56	493 [d]	54	492 [d]	61	542 [d]
Dental Clinics in Health Clinics [e]	-	-	583	1,446 [d]	586	1,442 [d]	577	1,581 [d]

Year	2011		2015		2017		2019	
	Number	Beds (Official)	Number	Beds (Official)	Number	Beds (Official)	Number	Beds (Official)
Dental Clinics in Hospitals	-	-	66	353 [d]	69	407 [d]	74	481 [d]
Dental Clinics in Other Institutes	-	-	16	17 [d]	20	17 [d]	21	21 [d]
School Dental Clinics	-	-	925	843 [d]	923	832 [d]	920	810 [d]
Mobile Dental Clinics	27	27 [d]	28	44 [d]	35	53 [d]	34	56 [d]
Sub-total	3,116	498	3,162	549	3,193	557	3,215	609
Registered Private Entities								
Private Medical Clinics	6,589	-	7,146	-	7,571	-	7,988	-
Private Dental Clinics	1,576	-	1,867	-	2,137	-	2,507	-
Sub-total	8,165	-	9,013	-	9,708	-	10,495	-
Secondary and Tertiary Services – Ministry of Health								
Hospitals	132	33,812	134	36,447	135	37,470	135	38,131
Special Medical Institutions	6	4,582	9	4,942	9	4,832	9	4,805
Sub-total	138	38394	143	41389	144	42302	144	42,936
Non-Ministry of Health								
Hospitals	8	3,322	9	3,698	10	3,892	10	4,052
Licensed Private Facilities								
Hospitals	220	13,568	183	12,963	240	15,566	208	16,469
Maternity Homes	25	105	14	50			18	52
Nursing Homes	14	362	16	539			21	775
Hospice	4	38	3	22			3	29
Sub-total	263	14,073	216	13,574	240	15,566	250	17,505
Grand Total	11,805	56,297	12,886	59,228	13,648	61,790	14,109	64,504

Note:
[a] Health clinics include Maternal and Child Health Clinics
[b] Number of helicopters
[c] Number of teams of Air Land Force
[d] Number of dental chairs
[e] Includes dental clinics in Maternal and Child Health Clinics
Source: Health Facts 2012, 2016, 2018, 2020, Ministry of Health

1.11 Economy

1.11.1 Gross Domestic Product and Gross National Income

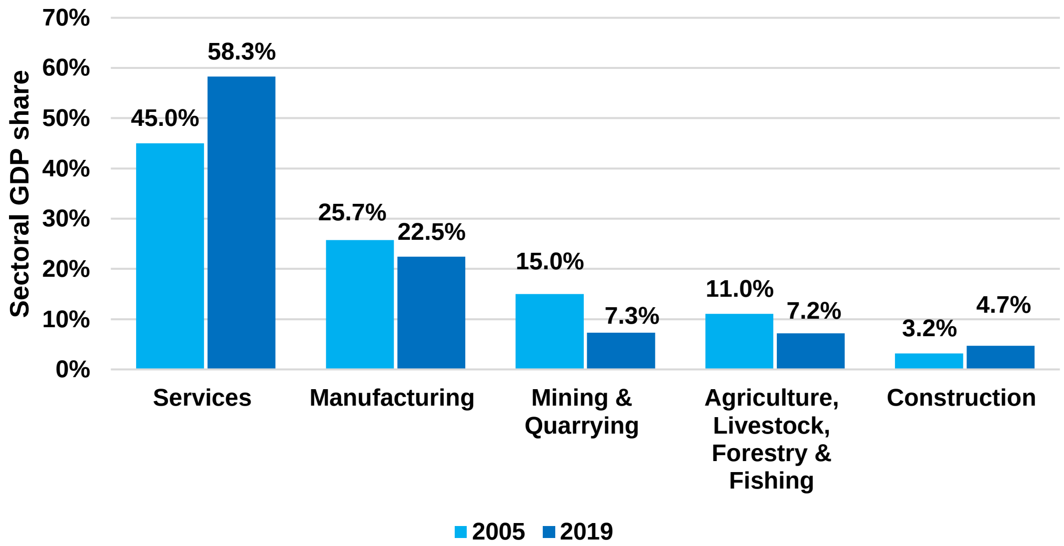
The Gross Domestic Product (GDP) of Malaysia has shown an upward trend since 2005 with an average of 4.88% growth rate at constant price from 2015 to 2019. GDP per capita at constant 2015 price grew from RM37,739 in year 2015 to RM43,783 in year 2019. Table 1.10 shows a summary of the GDP and GNI of Malaysia.

Table 1.10: GDP and GNI at Current and Constant Prices

Year	Gross Domestic Product (GDP)		Gross National Income (GNI)		GDP per capita	GNI per capita
	RM Billion				RM	
	Current Prices	Constant Prices (2015 = 100)	Current Prices	Constant Prices (2015 = 100)	Constant Prices (2015 = 100)	Constant Prices (2015 = 100)
2005	543.578	729.851*	519.635	735.823*	28,022*	28,251*
2015	1,176.941	1,176.941	1,144.829	1,155.866	37,739	37,063
2016	1,249.698	1,229.312	1,215.105	1,211.301	38,861	38,292
2017	1,372.310	1,300.769	1,333.652	1,281.719	40,620	40,025
2018	1,447.760	1,363.766	1,402.677	1,335.058	42,115	41,228
2019	1,512.738	1,423.952	1,473.242	1,402.096	43,783	43,111

Sources: Department of Statistics Malaysia, *calculated by NRES

Figure 1.6: Sectoral contribution shares to GDP for 2005 and 2019 International Trade



Note:
Contribution before adding import duties; GDP is at Constant Prices 2015
Source: Economics Planning Unit, Prime Minister's Department

Figure 1.6 shows the sectoral contributions to GDP in 2005 and 2019. Services and construction sector shows an increased contribution to the GDP in 2019 compared to 2015 while significant decrease of contribution was observed in the Manufacturing, Mining & Quarrying and Agriculture, Livestock, Forestry & Fishing sectors.

1.11.2 International Trade

Trade is an essential part of the Malaysian economy with Malaysia practising an open trade regime. In 2019, the Malaysian economy had a net balance of trade of RM145 billion, with exports totalling to RM995 billion and imports of RM849 billion. Table 1.11 shows Malaysia's annual trade for the selected years.

Table 1.11: Summary of Malaysia's Annual Trade

Year	(RM Million)			
	Gross Exports	Gross Imports	Total Trade	Balance of Trade
2005	536,234	432,871	969,104	103,363
2015	777,355	685,778	1,463,134	91,577
2016	786,964	698,819	1,485,783	88,145
2017	934,927	836,422	1,771,349	98,505
2018	1,003,587	879,804	1,883,391	123,783
2019	995,072	849,411	1,884,483	145,661

Source: Ministry of Economy

In 2019, manufactured goods formed the backbone of the export economy at 84.5% with electrical and electronic products accounting for 37.5% of the total export share. Primary industries goods made up 14.8% of export consisting mainly of palm oil and palm oil-based agriculture products (4.4%), liquified natural gas (4.3%) and crude petroleum (2.6%). Import-wise, intermediate goods made up 55%, followed by capital goods at 11.8% and consumption goods at 8.7%.

1.11.3 Unemployment

The unemployment rate decreased marginally from 3.5% in 2005 to 3.3% in 2019. Table 1.12 shows the changes in unemployment rate from 2005.

Table 1.12: Unemployment Rate

Year	Unemployment Rate (%)
2005	3.5
2015	3.1
2016	3.4
2017	3.4
2018	3.3
2019	3.3

Source: Department of Statistics Malaysia

1.12 Energy

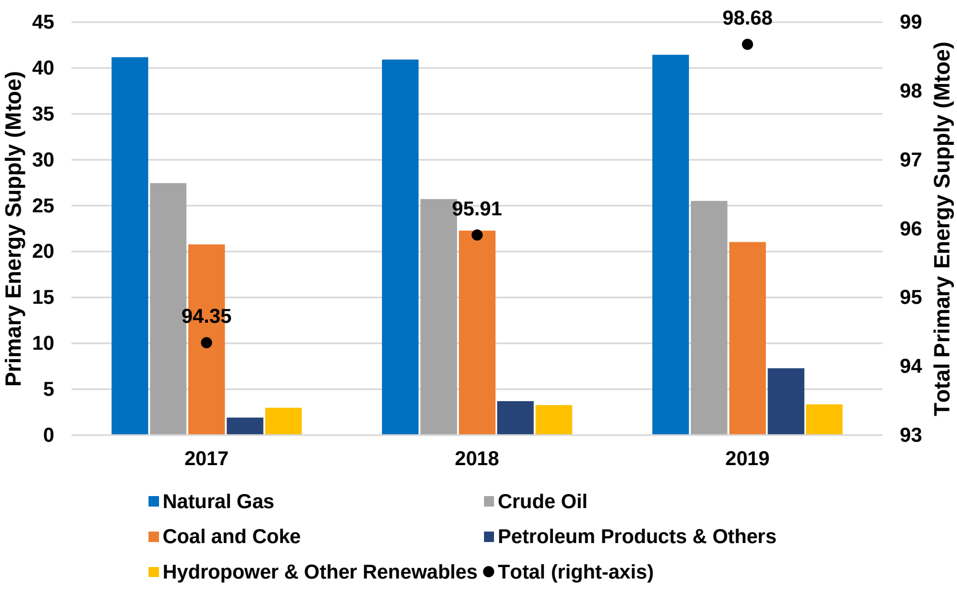
1.12.1 Policies

The energy sector is anticipated to strengthen access to affordable, reliable and sustainable energy, in line with Sustainable Development Goal 7 of the 2030 Agenda for Sustainable Development. The National Energy Policy 2022 – 2040, introduced in September 2022 underscores the commitment towards energy transformation with a focus to shift from fossil-based systems of production and consumption to renewable energy. The policy aligns the energy sector to the country's long-term plan of Shared Prosperity Vision 2030 and its five Key Economic Growth Activities which are directly related to the energy sector (such as sustainable mobility, renewable energy and green economy). The policy aims to spur new energy-related sectors which will also support the goal of reducing dependence on petroleum-based revenue and commodity trade, enhancing the resilience of the country's fiscal and economic position in the process. The policy also sets the directive towards Low Carbon Nation Aspiration 2040 from the improvement of primary energy mix intensity through increased penetration of clean and renewable sources of energy. This is in line with the Government's target to reach 31% of RE installed capacity mix by 2025.

1.12.2 Energy Balance

Malaysia's primary energy supply in 2019 was 98,680 ktoe with oil and gas as the main source of primary energy supplies. However, renewable energy contribution shows an increasing trend. Figure 1.7 shows a summary of Malaysia's primary energy supply in 2019 and Table 1.13 shows the breakdown in selected years from 2005 to 2019.

Figure 1.7: Primary Energy Supply Breakdown for 2017, 2018 and 2019



Source: National Energy Balance 2019, Energy Commission

Table 1.13: Primary Energy Supply Breakdown in selected years

Year	Primary Energy Supply Breakdown (ktoe)				
	Natural Gas	Crude Oil and Petroleum Products	Coal and Coke	Renewable Energy	Total
2005	33,913	24,096	6,889	446	65,344
2015	41,853	29,165	17,406	2,017	90,441
2016	41,257	31,327	18,744	2,420	93,748
2017	41,200	29,380	20,771	2,994	94,345
2018	40,939	29,429	22,280	3,261	95,909
2019	41,461	32,813	21,057	3,349	98,680

Source: National Energy Balance 2019

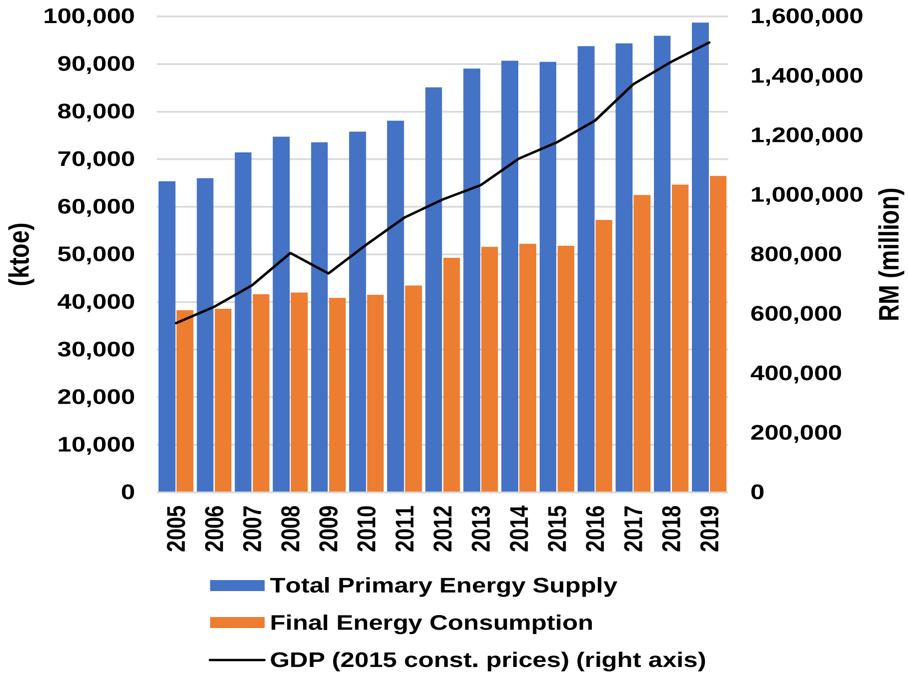
Malaysia's final energy consumption for year 2019 was 66,483 ktoe compared to 51,829 ktoe in 2015. Energy consumption according to sectors is shown in Table 1.14. As Malaysia economy grows, energy demands trend increased along with GDP as shown in Figure 1.8. In terms of GDP per capita and final energy consumption per capita, the trends are shown in Figure 1.9.

Table 1.14: Final energy consumption by sector

Year	Final Energy Consumption (ktoe)					
	Transport	Industry	Residential and Commercial	Non-energy use	Agriculture	Total
2005	15,293	15,583	5,134	2,173	101	38,284
2015	23,435	13,971	7,600	5,928	895	51,829
2016	24,004	16,019	8,051	8,729	415	57,218
2017	24,039	17,463	7,796	12,517	674	62,489
2018	23,555	19,046	7,773	13,262	1,021	64,657
2019	25,004	18,921	8,000	13,631	927	66,483

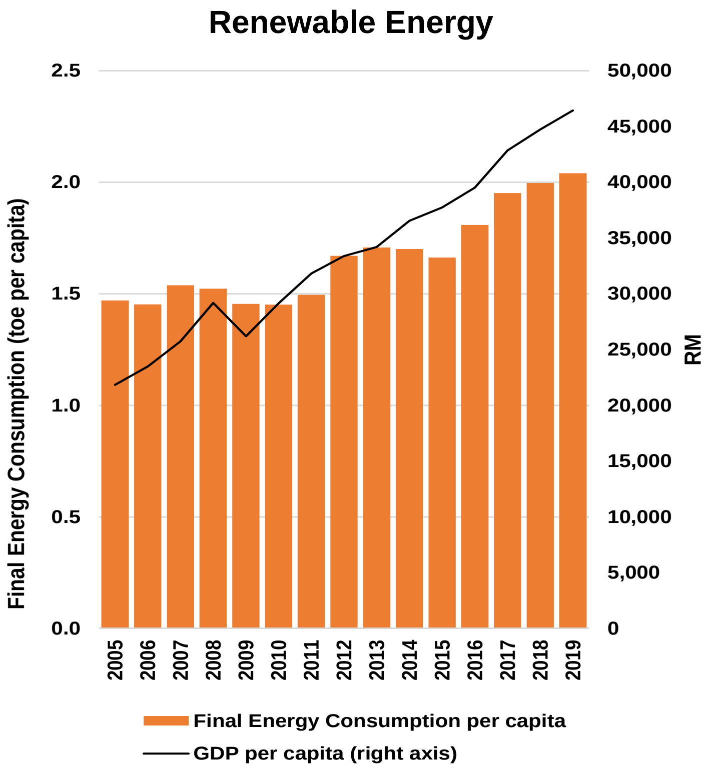
Note: Transport sector final energy use included international civil aviation fuel.
Source: National Energy Balance 2019

Figure 1.8: Trends in GDP, Primary Energy Supply and Final Energy Consumption



Sources: National Energy Balance 2019 Energy Commission and Ministry of Economy

Figure 1.9: Trends in Final Energy Consumption per capita and GDP per capita



Sources: National Energy Balance 2019, Energy Commission and Department of Statistic

1.12.3 Renewable Energy

BUR3 has provided detailed information on its policy and implementation. The update of the FiT programme is highlighted in Table 1.15 and Table 1.16.

Table 1.15: Cumulative Installed Capacities of Grid-connected FiT Renewable Energy Projects

Year	Capacity (MW)				
	Biogas	Biomass	Small Hydro	Solar PV	Total
2015	20.23	76.70	18.30	263.87	379.10
2016	35.69	87.90	30.30	341.69	495.58
2017	61.79	95.55	30.30	378.41	566.05
2018	69.94	70.65	50.30	384.62	575.51
2019	102.76	70.65	70.30	386.93	630.64

Source: SEDA Annual Report 2020

Table 1.16: Annual Power Generation of Commissioned FiT Renewable Energy Installations

Year	Power Generated (GWh)				
	Biogas	Biomass	Small Hydro	Solar PV	Total
2015	63.34	246.73	56.66	277.50	644.23
2016	107.11	248.48	50.28	359.54	765.41
2017	216.33	247.21	75.55	424.16	963.25
2018	251.78	226.09	89.67	467.89	1,035.43
2019	314.29	225.22	220.60	471.90	1,232.01

Source: SEDA Annual Report 2020

Other renewable energy programmes are the Large-Scale Solar (LSS), Nett Energy Metering (NEM) and hydropower. The installed capacity of all the renewable energy sources for the whole Malaysia is shown as the Table 1.17 below.

Table 1.17: Total Installed Capacities of Renewable Energy in Malaysia

Year	Capacity (MW)			
	Hydro	Biomass	Solar	Biogas
2015	5,176.1	862.5	226.3	111.3
2016	6,128.1	742.4	289.6	34.6
2017	6,128.7	748.2	357.6	70.0
2018	6,167.9	552.4	797.1	80.1
2019	6,190.1	440.5	996.4	146.2

Source: National Balance 2015 – 2019, Energy Commission

1.13 Transport

The Land Public Transport Agency (APAD) replaced the Land Public Transport Commission (SPAD) in June 2018, taking over its function of developing Malaysia's land public transport system including the mass rail transit (MRT), light rail transit (LRT), rail transportation and bus systems. The Agency is tasked with 'spearheading the transformation of an integrated, efficient and safe transportation system'. A National Transport Policy (2019-2030) was launched to increase the public transport modal share (40% by 2030) in urban areas while also implementing sustainable measures across all transport modes.

1.13.1 Roads

The length of roads has increased substantially from 90,016 km in 2005 to 258,511 km in 2019.This is primarily due to extensive expansion of state roads in the past decade leading to greater intra-state and interstate accessibility. Table 1.18 highlights the historical changes in lengths of roads.

Table 1.18: Length of Roads

Year	Length of roads (km)			
	State Roads	Federal Roads	Toll Highways	Total
2005	70,749	17,764	1,503	90,016
2015	197,015	19,822	1,984	218,821
2016	218,988	19,802	1,988	240,778
2017	217,072	19,950	2,001	239,023
2018	227,646	19,809	1,960	249,415
2019	236,581	19,912	2,018	258,511

Source: Public Works Department, Ministry of Works and Malaysia Highway Authority

1.13.2 Motor-vehicle

Motor-vehicle registration has more than doubled from 2005 to 2019. Total registrations in 2019 were 31,214,772 compared to 14,816,407 in 2005. Table 1.19 shows the trend in motor-vehicle registration on a yearly basis.

Table 1.19: Motor-Vehicle Registration

Year	Motorcars	Motorcycles	Taxi & Hired Cars	Buses	Goods Vehicles	Others*	Total
2005	6,473,261	7,008,051	79,130	57,370	805,157	393,438	14,816,407
2015	11,871,696	12,094,790	172,034	66,999	1,197,987	898,446	26,301,952
2016	13,000,358	12,677,220	124,020	59,969	1,190,664	561,028	27,613,259
2017	13,582,636	13,173,069	122,172	61,059	1,223,396	575,844	28,738,176
2018	14,191,338	13,725,946	123,395	62,003	1,261,598	592,194	29,956,474
2019	14,695,664	14,322,226	120,134	62,966	1,295,486	718,296	31,214,772

Note:
*Including Government motorcars, trailers, and driving school vehicles
Source: Ministry of Transport and Land Public Transport Agency

1.13.3 Urban Rail Transit

The rail network is crucial to the Malaysia's transport system as it enables greater domestic mobility. By the end of 2016, there were five urban rail network lines serving the Greater Kuala Lumpur namely KTM Komuter, LRT Ampang Line, LRT Kelana Jaya Line, KL Monorail and the MRT. The total ridership of rail transit and commuter trains is shown in Table 1.20.

The KTM Komuter service was first introduced in 1995 and was intended to serve interstate and within Greater Kuala Lumpur's radial corridors. Both the LRT Ampang Line (27 km) and the LRT Kelana Jaya Line (29 km) commenced operations in the city on 16 December 1996 and on 1 September 1998 respectively. The 8.6 km KL Monorail was built over an elevated track and commenced operations on 31 August 2003. In 2002, the KLIA Ekspres and the KLIA Transit were launched. The KLIA Ekspres is a high-speed, non-stop rail connection between KLIA, KLIA2 and the KL Sentral, providing a mass rail transportation option in support of the civil aviation industry. On the other hand, the KLIA Transit is a commuter service that stops at three intermediate stations. To accommodate the highly populated areas, both LRT lines – Ampang and Kelana Jaya – were extended to 45 km in total length for LRT Ampang and 46 km for LRT Kelana Jaya. The extended length went into operation on 30 June 2016.

The first MRT line – the 46 km Kajang Line - commenced service in July 2017. Phase One of the 57.7 km second line (Putrajaya Line) began operation on 16 June 2022. Phase Two of the Putrajaya Line is due for completion in the first quarter of 2023.

Table 1.20: Total Ridership of Rail Transit and Commuter Trains

	2005	2015	2016	2017	2018	2019
LRT Kelana Jaya Line	60,290,467	82,144,674	79,002,839	83,585,412	87,216,597	94,657,974
LRT Ampang Line	45,636,997	62,809,412	59,192,907	59,462,032	60,960,445	65,147,222
KL Monorail	16,206,441	25,067,866	21,990,242	16,841,630	12,594,377	12,535,738
KTM-Komuter	30,934,651	49,690,000	41,407,104	37,235,410	32,036,271	30,327,420
ERL KLIA Express*	2,075,105	3,470,710	2,419,883	2,275,650	2,195,353	2,155,855
ERL KLIA Transit	2,331,741	6,496,617	6,485,272	6,443,667	6,541,505	6,788,121
MRT**	N.A.	N.A.	N.A.	22,350,508	51,314,240	63,952,805

Note:
* Started operation in 2002.
**Started operation in December 2016.
Source: Ministry of Transport and Public Land Transport Agency

1.13.4 Inter-city Railway Statistics

Malaysia has expanded its total railway route length from 1,665 km to 1,799 km during the period of 2005 to 2019. At the same time, it has also increased the length of electrified railway tracks. The Electric Train Service (ETS) provides intercity train service. These infrastructures are in Peninsular Malaysia while a single track of 134 km operates in the state of Sabah in Borneo. There are no railway services in the state of Sarawak. Table 1.21 summarises the railway statistics for Peninsular Malaysia up to 2019.

Table 1.21: Railway statistics for Peninsular Malaysia

	Unit	2005	2015	2016	2017	2018	2019
Total Railway Route Length	km	1,665	1,641	1,705	1,833	1,799	1,799
Electrified Track Railway Route Length	km	151	774	955	1,014	1,014	1,014
Total Number of Rail Passenger*	million	3.68	2.01	2.79	3.09	3.53	3.75
Rail-passenger kilometre	million	1,181	407	272	180	178	183
ETS passenger**	million	N.A	2.06	3.57	4.15	3.93	3.90
ETS passenger kilometre**	million	N.A	441	996	1,189	1,127	1,112
Freight	million tonne	4.03	6.21	5.99	5.62	5.94	5.97
Freight-kilometre	million tonne km	1,178	1,474	1,349	1,234	1,314	1,141

Note:
*KTM intercity ridership only
** connotes that this commuter service started operations in August 2010
Source: Ministry of Transport and Land Public Transport Agency

1.13.5 Stage Bus Services

Table 1.22 provides information on the ridership of stage buses in selected capital cities. The Stage Bus Service Transformation (SBST) was introduced in 2015 to improve operator viability and expand bus route coverage. However, annual ridership of stage buses has been declining since 2017 in most cities except Georgetown and Kota Bharu.

Table 1.22: Stage Bus Annual Ridership in Selected Capital Cities

Cities	2015	2016	2017	2018**	2019
Kangar	212	285	404	361	350
Alor Setar	1,469	1,198	999	682	488
Georgetown	18,947	13,075	12,363	15,604	16,165
Ipoh	5,657	4,733	4,189	3,224	3,500
Shah Alam	12,238	N/A	N/A	N/A	N/A
Seremban	3,886	4,008	4,265	3,274	2,979
Melaka	4,887	4,455	3,319	2,078	1,402
Johor Bahru	21,000	18,051	15,418	1,248	1,222
Kuantan	4,486	4,298	3,799	3,403	2,932
Kuala Terengganu	187	312	183	281	273
Kota Bharu	3,047	2,281	1,976	1,739	1,921
Total Annual Ridership	76,016	52,696*	46,915*	31,894*	31,232*

Note:
* Connotes exclusion of ridership figures for Shah Alam in 2016, 2017, 2018 and 2019
**Some ridership figures for non-SBST programme reported for Jan-Nov 2018
Sources: Ministry of Transport and Public Land Transport Agency

1.13.6 Air Traffic Statistics

Between 2005 and 2019, there has been a general increase of air traffic passengers for both domestic and international air travel. The total number of domestic embarked and disembarked passengers increased from 22.4 million in 2005 to 55.5 million in 2019. The number of international embarked and disembarked international passengers increased from 16.6 million to 53.8 million for the same period. Table 1.23 summarises the trend in air travel.

Table 1.23: Yearly Total Number of Domestic and International Passengers Handled by Airports

Year	Domestic			International		
	Embarked	Dis-embarked	Total	Embarked	Dis-embarked	Total
2005	10,456,749	11,954,473	22,411,222	8,267,880	8,298,555	16,566,435
2015	22,975,852	22,955,192	45,931,044	20,177,309	19,839,826	40,017,135
2016	13,995,425	23,970,410	37,965,835	22,026,087	21,464,612	43,490,699
2017	24,878,045	24,861,535	49,739,580	25,196,175	24,588,035	49,784,210
2018	25,080,393	25,105,859	50,186,252	26,371,319	25, 875,483	52,246,802
2019	27,730,091	27,792,327	55,522,418	27,358,552	26,482,106	53,840,658

Note: *connotes that information is from Malaysia Airports Holdings Berhad
Sources: Ministry of Transport, Malaysia Airports Holdings Berhad

Between 2005 and 2019, domestic cargo handled has increased from 119,685 tonnes to 189,400 tonnes while international cargo handled has shrunk from 775,313 tonnes to 753,227 tonnes. However, the trend flattens for both domestic and international cargo handled between 2015 to 2019 as reflected in Table 1.24.

Table 1.24: Yearly Total Domestic and International Cargo Handled by Airports

Year	Domestic (tonnes)			International (tonnes)		
	Loaded	Unloaded	Total	Loaded	Unloaded	Total
2005	61,705	57,979	119,685	421,790	353,523	775,313
2015	99,674	92,876	192,550	373,795	392,698	766,493
2016	95,968	92,981	188,949	331,350	353,134	684,485
2017	97,945	91,346	189,291	367,061	391,839	758,900
2018	104,624	92,741	197,365	361,090	407,345	768,435
2019	99,702	89,698	189,400	347,667	405,559	753,226

Sources: Ministry of Transport, Malaysia Airports Holdings Berhad

1.14 Agriculture

In 2011, policies on food production and agro-commodities were separated and developed under two distinct policy documents, namely the National Agrofood Policy (2011-2020) and the National Commodity Policy (2011-2020). For the post 2020 period, agriculture development is being guided by the National Agrofood Policy 2021-2030 and the National Agri-Commodity Policy 2021-2030. Sustainable development is a key principle in both policies besides strengthening the two subsectors' contributions to food security and socio-economic development.

1.14.1 Agricultural Crops

The agriculture area consists of primarily commodity crops such as oil palm, rubber and cocoa. Paddy is also an important agricultural crop and the planted areas involved double cropping. Table 1.25 reflects the changes in planted areas of major agricultural crops in selected years between 2005 and 2019.

Table 1.25: Planted Areas of Major Agricultural Crops

Year	Crops ('000 ha)			
	Rubber	Oil Palm	Cocoa	Paddy
2005	1,271.3	4,051.4	34.0	666.8
2015	1,074.5	5,642.9	18.1	681.6
2016	1,078.0	5,738.0	17.4	688.8
2017	1,081.7	5,811.1	17.5	685.5
2018	1,127.0	5,849.3	15.6	699.9
2019	1,131.9	5,900.1	5.9	672.1

Sources: Ministry of Agriculture and Food Security; Ministry of Plantation and Commodities

1.14.2 Livestock

Livestock population size fluctuation across all animal types has largely remain stable between 2015 and 2019. Table 1.26 shows the livestock population from 2005 to 2019.

Table 1.26: Selected livestock populations

Year	Livestock							
	Buffalo	Cattle	Goat	Sheep	Swine	Horse*	Chicken	Duck
2005	133,232	790,065	287,670	115,922	2,035,647	2,367	174,694,165	8,052,997
2015	118,569	742,338	431,651	147,033	1,886,823	3,608	286,620,834	9,897,115
2016	119,133	737,827	416,529	138,479	1,654,381	4,145	289,666,002	9,633,185
2017	114,013	703,832	385,304	130,658	1,849,351	4,306	293,301,558	9,283,900
2018	106,988	676,686	359,200	128,298	1,967,538	4,204	260,826,321	9,780,573
2019	101,695	657,407	312,571	121,677	1,888,460	3,095	285,063,636	9,376,456

Sources: Agrofood Statistics 2020, Ministry of Agriculture and Food Security; Department of Veterinary Services (DVS) Livestock Statistics, (*) FAOSTAT

1.14.3 Fisheries and Aquaculture

Landings of marine fish (including shellfish collection) in Malaysia has had a slight increase from 1.21 million tonnes in 2005 to 1.45 million tonnes in 2019. Table 1.27 below summarises the change in landings of marine fish.

Table 1.27: Landings of Marine Fish

Year	Landings of Marine Fish ('000 tonnes)
2005*	1,210
2015	1,486
2016	1,574
2017	1,465
2018	1,453
2019	1,455

Sources: Agrofood Statistics 2020, Ministry of Agriculture and Food Security and *Annual Fisheries Statistics, Department of Fisheries

Aquaculture production in Malaysia increased from 207,000 tonnes in 2005 to 412,000 tonnes in 2019. Fresh water aquaculture activities carried out in ponds, ex-mining pools, cages, cement tanks as well as pen cultures contributed 105,000 tonnes, while brackish water/marine aquaculture cultivated in ponds, cages and water tanks contributed 307,000 tonnes. Table 1.28 shows the growth of aquaculture according to the two production systems.

Table 1.28: Aquaculture production – Brackish and Coastal Areas

Year	Freshwater ('000 tonnes)	Brackish Water/Marine ('000 tonnes)	Total ('000 tonnes)
2005*	62	145	207
2015	112	394	506
2016	103	304	407
2017	103	324	427
2017	101	290	391
2019	105	307	412

Sources: Agrofood Statistics 2020, Ministry of Agriculture and Food Industries and *Annual Fisheries Statistics, Department of Fisheries

1.15 Solid Waste

Waste generation increases in tandem with population growth. Table 1.29 provides a breakdown of average daily waste generation by region for year 2007 and 2012 while Table 1.30 presents the number of both sanitary and non-sanitary landfills according to states in 2019.

Table 1.29: Average Waste Generations Per Day in 2007 and 2012

Region	Year	
	2007	2012
Peninsular Malaysia (tonnes/day)	20,500	27,802
Sabah (tonnes/day)	1,210	2,984
Sarawak (tonnes/day)	1,988	2,344
Total (tonnes/day)	23,698	33,130

Source: Survey on Solid Waste Composition, Characteristics and Existing Practice of Solid Waste Recycling in Malaysia 2012, National Solid Waste Management Department

Table 1.30: Number of Landfills in Malaysia in 2019

State	Landfills in operation		Total
	Sanitary	Non-Sanitary	
Johor	1	8	9
Kedah	2	2	4
Kelantan	0	10	10
Melaka	1	0	1
Negeri Sembilan	1	2	3
Pahang	2	8	10
Perak	1	15	16
Perlis	1	0	1
Pulau Pinang	1	0	2*
Sabah	1	21	22
Sarawak	3	43	46
Selangor	3	2	8*
Terengganu	1	8	9
WP Labuan	1	0	1
WP KL/Putrajaya	0	0	0
Total	19	119	142*

Note: *Including inert landfill site(s); 1 in Pulau Pinang, 3 in Selangor
Source: National Solid Waste Management Department

The solid waste composition of Malaysia for the years 2004 and 2012 (latest date of last survey of the Solid Waste sector) is shown in Table 1.31. Food waste, while decreasing, remains the biggest proportion waste and there is an increase of wood, textiles, diapers and plastic in the waste composition in 2012.

Table 1.31: Solid Waste Composition

Composition	Percentage (%)	
	2004 (JICA Study)	2012
Food waste	49.3	44.5
Garden Waste	6.6	5.8
Paper	17.1	8.5
Wood	0.2	1.4
Textiles	3.7	5.2
Diapers	5.1	12.1
Plastic and Other Inerts	18.1	22.2

Note: JICA – Japan International Cooperation Agency
Source: Survey on Solid Waste Composition, Characteristics and Existing Practice of Solid Waste Recycling in Malaysia 2012, National Solid Waste Management Department.

1.16 Summary of Key Statistics

Table 1.32 provides a summary of key statistics for 2005 and 2019.

Table 1.32: Key Statistics for 2005 and 2019

Year	2005	2019
Latitude	$0^{o}\,51^{'}$ N - $7^{o}\,33^{'}$ N	
Longitude	$98^{o}\,01^{'}$ E – $119^{o}\,30^{'}$ E	
Area	330,241 km^2	
Coastline	4,809 km	
Mean daily temperature	26 – 28 ^{o}C	
Average annual rainfall	2,000 – 4,000 mm	
Average daily direct sunlight	6 hours	
Forest Cover as % of total land area	53.9% (estimate)	54.9% (estimate)
Population	26.0 million	32.5 million
Population density	79 per km^2	99 per km^2
Female life expectancy	76.0 years	77.4 years
Male life expectancy	71.4 years	72.5 years
Age Profile	Below 15 years old – 30.9% 15 to 64 years old – 64.6% Above 65 years old – 4.5%	Below 15 years old – 23.5% 15 to 64 years old – 69.8% Above 65 years old – 6.7%
Urbanisation Rate	66.5%	76.2%
GDP (at 2015 constant prices)	RM 729,851 million	RM 1,424,310 million

Year	2005	2019
GNI/capita (at 2015 constant prices)	RM 28,251	RM 43,111
Primary Energy Supply	65,344 ktoe	98,680 ktoe
Final Energy Demand	38,284 ktoe	66,483 ktoe
Total Electricity Consumption	80,705 GWh	158,603 GWh
Length of roads (Federal, State and Toll Highways)	90,016 km	258,511 km
Motor vehicle registration	14,816,407	31,214,772
Annual Ridership on urban rail network in Greater Kuala Lumpur/ Klang Valley (passenger journeys)	157,475,402	275,565,135
Annual ridership on Stages Buses (11 towns and cities) (passenger journeys)	-	31,232
Solid Waste	-	33,130 tonnes/day (2012)

1.17 Institutional Arrangements

The institutional arrangements support three key areas of climate change action: policy making, development planning and implementation, and guidance and reporting. It should be highlighted that since the Third National Communication (NC3), Malaysia had experienced three rounds of changes in Government and ministerial restructuring. Changes during the first two rounds were reported in the Third Biennial Update Report (submitted December 2020) and the latest round being the most recent change in federal power which is detailed below.

1.17.1 Restructuring of Ministries in 2022

Following the results of the 15th General Election in November 2022, the two key ministries for climate change were merged. The Ministry of Environment and Water, which was the focal point ministry to the UNFCCC since 2020 and the Ministry of Energy and Natural Resources were combined to form the Ministry of Natural Resources, Environment and Climate Change (NRECC). Subsequently, as of the end of December 2023, it underwent further transformation into the Ministry of Natural Resources and Environmental Sustainability (NRES). This ministry now takes on the role of the national focal point for climate change within the UNFCCC framework.

In addition, several ministries and the central planning agency had undergone restructuring and/or renaming as listed below:

(a) Ministry of Agriculture and Food Industries to Ministry of Agriculture and Food Security;
(b) Ministry of Domestic Trade and Consumer Affairs to Ministry of Domestic Trade and Cost of Living;
(c) Ministry of Housing and Local Government to Ministry of Local Government Development;

(d) Ministry of Plantation Industries and Commodities to Ministry of Plantation and Commodities; and
(e) Economic Planning Unit, Prime Minister's Department to Ministry of Economy.

1.17.2 Policy Making

The Malaysia Climate Change Action Council (MyCAC) was established to address the policy direction of climate change in December 2020. It is chaired by the Prime Minister and has key Cabinet Ministers and state leaders as members.

The Cabinet is the highest policy decision-making body in the country on climate change matters under the purview of the Minister of Natural Resources and Environmental Sustainability (NRES). Any decisions taken at the MyCAC and other bodies require a final endorsement by the Cabinet.

1.17.3 Development Planning and Implementation

Development planning and implementation is coordinated by the Ministry of Economy in consultation with other Ministries. These are carried out through the five-year development plans and include climate change mitigation and adaptation programmes. Table 1.33 shows the coordinating Ministries and their respective implementing agencies for key sectors.

Table 1.33: Coordinating Ministries and Their Respective Agencies Responsible for Climate Actions

Area	Sector/Area	Coordinating Ministries	Associated Implementing Ministries/State Ministries/Agencies
Greenhouse Gas Inventory	All IPCC Sectors	Ministry of Natural Resources and Environmental Sustainability	Ministry of Natural Resources and Environmental Sustainability (Energy, LULUCF and waste sectors) Ministry of Plantation and Commodities (Agriculture, LULUCF and waste sectors) Ministry of Agriculture and Food Security (Agriculture sector) Energy Commission (Energy sector) Forest Research Institute Malaysia (LULUCF sector)

Area	Sector/Area	Coordinating Ministries	Associated Implementing Ministries/State Ministries/Agencies
			Department of Environment (Waste sector) Malaysia Agriculture Research and Development Institute (Agriculture sector) Department of Statistics Malaysia Institute of Energy Policy and Research, Universiti Tenaga Nasional (Energy and Industrial Processes and Product Use sectors)
Mitigation	Energy	Ministry of Economy and Ministry of Natural Resources and Environmental Sustainability	Energy Commission Sustainable Energy Development Authority Sabah State Economic Planning Unit Ministry of Energy and Environmental Sustainability Sarawak Sabah Electricity Sendirian Berhad Sarawak Energy Berhad PETRONAS
	Transport	Ministry of Transport	Land Public Transport Agency Marine Department Malaysia Civil Aviation Authority of Malaysia Ministry of Plantation and Commodities
	Industries	Ministry of Investment, Trade and Industry	Malaysia Investment Development Authority SME Corporation Malaysia Malaysia Automotive Institute

Area	Sector/Area	Coordinating Ministries	Associated Implementing Ministries/State Ministries/Agencies
			Ministry of Domestic Trade and Cost of Living Sabah State Economic Planning Unit Economic Planning Unit Sarawak
	Agriculture	Ministry of Agriculture and Food Security and Ministry of Plantation and Commodities	Department of Agriculture (Peninsular Malaysia, Sabah and Sarawak) Department of Veterinary Services (Peninsular Malaysia, Sabah and Sarawak) Malaysian Agriculture Research and Development Institute Malaysian Palm Oil Board Malaysian Rubber Board Malaysian Cocoa Board
	Forestry	Ministry of Natural Resources and Environmental Sustainability	Forestry Department Peninsular Malaysia Sarawak Forest Department Sabah Forestry Department Department of Wildlife and National Parks Peninsular Malaysia Sabah Parks Sabah Wildlife Department Sarawak Forestry Corporation

Area	Sector/Area	Coordinating Ministries	Associated Implementing Ministries/State Ministries/Agencies
	Waste	Ministry of Local Government Development and Ministry of Natural Resources and Environmental Sustainability	National Solid Waste Management Department Solid Waste Management and Public Cleansing Management Corporation Sewerage Service Department Department of Environment Malaysian Palm Oil Board Ministry of Local Government and Housing Sabah Ministry of Public Health, Housing and Local Government Sarawak State governments (Selangor, Pulau Pinang, Perak, Kelantan and Terengganu)
Adaptation	Water Resources	Ministry of Natural Resources and Environmental Sustainability	Department of Irrigation and Drainage National Water Services Commission National Water Research Institute of Malaysia Department of Mineral and Geoscience Ministry of Utility and Telecommunication Sarawak Sabah State Water Department
	Coastal Resources	Ministry of Natural Resources and Environmental Sustainability	Department of Irrigation and Drainage National Water Research Institute of Malaysia

Area	Sector/Area	Coordinating Ministries	Associated Implementing Ministries/State Ministries/Agencies
	Agriculture	Ministry of Agriculture and Food Security and Ministry of Plantation and Commodities	Department of Agriculture (Peninsular Malaysia, Sabah and Sarawak) Department of Veterinary Services (Peninsular Malaysia, Sabah and Sarawak) Department of Fisheries (Peninsular Malaysia and Sabah) Department of Marine Fisheries Sarawak Malaysian Agriculture Research and Development Institute Malaysian Palm Oil Board Malaysian Rubber Board Malaysian Cocoa Board
	Forestry and Biodiversity	Ministry of Natural Resources and Environmental Sustainability	Forestry Department Peninsular Malaysia Department of Fisheries Malaysia Department of Wildlife and National Parks Peninsular Malaysia Sabah Forestry Department Sabah Wildlife Department Sabah Parks Sarawak Forest Department Sarawak Forestry Corporation Ministry of Agriculture and Food Security (Division of Marine Parks)

Area	Sector/Area	Coordinating Ministries	Associated Implementing Ministries/State Ministries/Agencies
	Infrastructure and Housing	Ministry of Works, Ministry of Local Government Development and Ministry of Natural Resources and Environmental Sustainability	Public Works Department Local Government Department National Housing Department Federal Department of Town and Country Planning Sewerage Service Department Ministry of Local Government and Housing Sabah Ministry of Public Health, Housing and Local Government Sarawak
	Energy	Ministry of Economy and Ministry of Natural Resources and Environmental Sustainability	Energy Commission Sustainable Energy Development Authority PETRONAS
	Health	Ministry of Health	Institute for Medical Research Disease Control Division

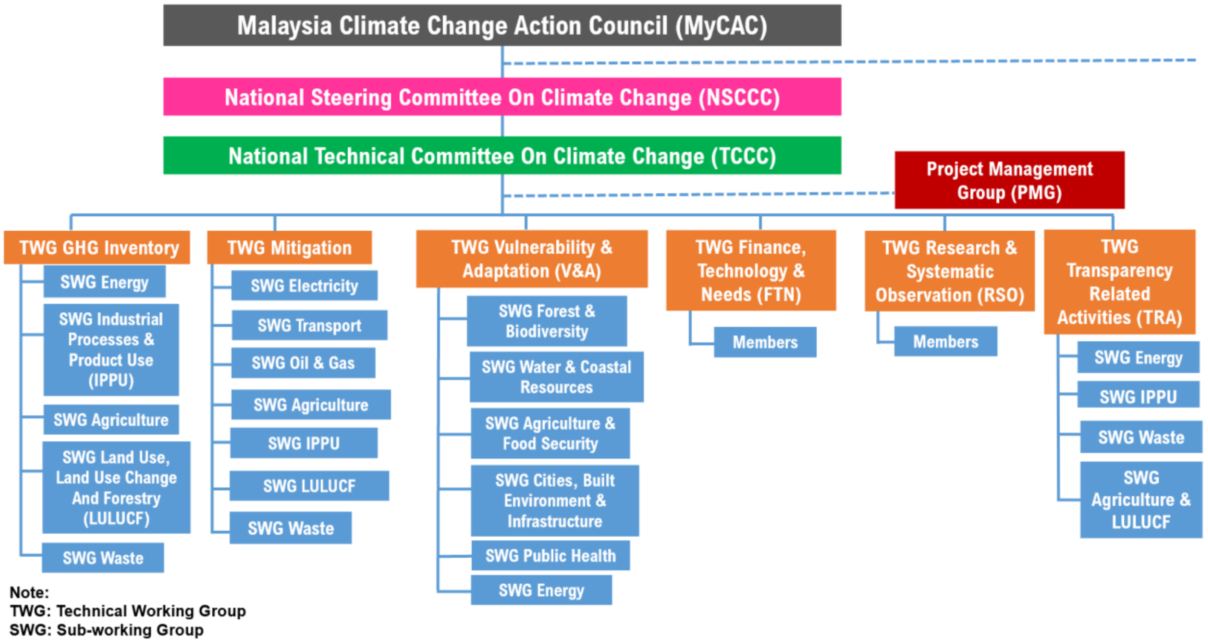
1.17.4 Guidance and Reporting

The National Steering Committee on Climate Change (NSCCC)

Operational matters on climate change are guided and endorsed by the National Steering Committee on Climate Change (NSCCC) chaired by the Secretary General of NRES. The coordination for the preparation of national communications (NCs) and biennial update reports (BURs) is under the Technical Committee on Climate Change (TCCC) which reports to the NSCCC.

The secretariat to these committees is the Climate Change Division of NRES which is also the national focal point for climate change to the UNFCCC. The technical work of the NCs and BURs is carried out through six Technical Working Groups (TWGs) established under the TCCC. Figure 1.10 shows the institutional arrangement and thematic groupings to address climate change and NC/BUR reporting.

Figure 1.10: Institutional Arrangement and Thematic Technical Working Groups for Climate Change



The National Steering Committee and Technical Working Committee for REDD Plus

At the national level, the National Steering Committee on REDD Plus (NSCREDD) was established in 2011 to formulate the directions and strategies for REDD plus implementation. The NSCREDD is chaired by the Secretary General of the NRES with membership from State Economic Planning Units, Forestry Departments and relevant Ministries. NSCREDD is supported by the Technical Working Committee on REDD Plus. The roles of this Technical Working Committee include providing methodological guidance on REDD plus implementation and formulating national action plans.

The National Committee on Clean Development Mechanism

The National Clean Development Mechanism (CDM) Committee was established in 2002 to guide CDM implementation. It is chaired by the Deputy Secretary-General of the NRES with the Secretary General being the Designated National Authority (DNA).

CHAPTER 2

2. NATIONAL GREENHOUSE GAS INVENTORY

2.1 Introduction

This chapter provides a summary analysis of the GHG Inventory of Malaysia for 2019. Estimations were carried out for four sectors, namely the energy, industrial processes and product used (IPPU), agriculture forestry and other land use (AFOLU), and waste sectors. In the analysis, the AFOLU sector would be presented as AFOLU-Agriculture (IPCC category 3A and 3C) and AFOLU-LULUCF (IPCC category 3B and 3D). Detailed information on the national GHG inventory for 2019 and time series from 1990-2019 had been reported in Malaysia's Fourth Biennial Update Report.

2.2 Institutional Arrangement

The institutional structure for the preparation of the national GHG inventory is shown in Figure 1.10 of chapter 1 (National Circumstances). The GHG inventory preparation is coordinated by the Climate Change Division under the Ministry of Natural Resources and Environmental Sustainability (NRES). The preparation of the inventory is steered by a GHG Inventory Technical Working Group (TWG) supported by five thematic Sub Working Groups (SWG), namely for the Energy, IPPU, Agriculture, Land Use, Land-use Change and Forestry (LULUCF) and Waste sectors. The TWG on GHG Inventory meets regularly to provide methodological guidance to ensure transparency, accuracy, completeness, consistency and comparability of the GHG inventory work carried out by the five sectoral SWGs.

2.3 Methodology for GHG Emissions Calculation

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories and 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, were used to estimate the GHG emissions and removals. Emission estimates were calculated for both reference and sectoral approaches for the energy sector. Time series were recalculated to reflect the updated methodologies, activity data, emission factors in accordance with these guidelines.

The estimated methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) emissions were converted to carbon dioxide equivalents (CO_2 eq.) using the 100-year time horizon global warming potential (GWP) values reported in the *IPCC Fourth Assessment Report* (AR4).

Comparison was also carried out to assess the differences in CO_2 eq. GHG emissions between using IPCC AR4 and AR5 100-year time horizon GWPs.

2.4 Improvements in Current GHG Inventory

Effort had been taken to compile a more complete and accurate 2019 GHG inventory than those GHG inventories reported in earlier National Communications and Biennial Update Reports. Table 2.1 shows the sub-categories included in the 2019 GHG inventory compared to the earlier inventory reported in NC3.

Table 2.1: Comparison of Sub-Categories within Sectors included in NC3/BUR2 and NC4/BUR4 GHG Inventories

Key categories	NC3/BUR2 2014 Inventory Year	NC4/BUR4 2019 Inventory Year
Energy		
Reference Approach	√	√
Sectoral Approach ● Fuel Combustion Activities	√	√
➢ Energy Industries	√	√
○ Main Electricity and Heat Production	√	√
○ Petroleum Refining	√	√
○ Other Energy Industries	√	√
➢ Transport	√	√
○ International Aviation	√	√
○ Domestic Aviation	√	√
○ Road Transportation	√	√
○ Railways	√	√
○ International Water-borne Navigation	√	√
○ Domestic Water-borne Navigation	√	√
○ Other Transportation (Off-road)	NE	√
➢ Manufacturing Industries and Construction	√	√
➢ Other Sectors	√	√
○ Institutional/Commercial	√	√
○ Residential	√	√
○ Agriculture/ Forestry/Fishing/Fish Farms	√	√
➢ Non-Specified	√	√
● Fugitive Emissions from Fuels	√	√
➢ Solid Fuels	√	√
➢ Oil and Natural Gas	√	√
Industrial Processes and Product Use		
● Mineral Industry	√	√
➢ Cement Production	√	√
➢ Lime Production	√	√
➢ Glass Production	√	√
➢ Other Process Use of Carbonates	√	√
● Chemical Industry	√	√
➢ Ammonia Production	√	√
➢ Carbide Production	√	√
➢ Petrochemical and Carbon Black Production	√	√
● Metal Industry	√	√

Key categories	NC3/BUR2 2014 Inventory Year	NC4/BUR4 2019 Inventory Year
➢ Iron & Steel Production	√	√
➢ Aluminium Production	√	√
➢ Ferroalloys Production	NE	√
• Electronics Industry	√	√
➢ Integrated Circuit or Semiconductor	√	√
➢ Photovoltaics	√	√
• Product Use as Substitutes to Ozone Depleting Substances	√	√
➢ Refrigeration and Air Conditioning (Mobile air conditioning)	√	√
• Other Product Manufacture and Use	√	√
➢ Electrical Equipment (SF_6 use)	√	√
➢ N_2O from Medical Applications	√	√
AFOLU – Agriculture		
• Enteric Fermentation	√	√
• Manure Management	√	√
• Biomass Burning	√	√
• Liming	√	√
• Urea Application	√	√
• Direct N_2O Emissions from Managed Soils	√	√
• Indirect N_2O Emissions from Managed Soils	√	√
• Indirect N_2O Emissions from Manure Management	√	√
• Rice Cultivations	√	√
AFOLU – Land Use Land-Use Change and Forestry		
• Forest Land remaining Forest Land	√	√
➢ Natural forest	√	√
➢ State land forest	√	√
• Cropland Remaining Cropland	√	√
➢ Plantation Crops	√	√
○ Oil Palm	√	√
○ Rubber	√	√
○ Cocoa	√	√
➢ Peatland Cultivation	√	√
• Grassland Remaining Grassland	NA	NA
• Wetland Remaining Wetland	NA	NA
• Settlement	√	√
➢ Settlement Remaining Settlement	NA	NA
➢ Forest land converted to Settlement	√	√
➢ Cropland converted to Settlement	√	√
Waste		
• Solid Waste Disposal	√	√

Key categories	NC3/BUR2 2014 Inventory Year	NC4/BUR4 2019 Inventory Year
• **Biological Treatment of Solid Waste**	√	√
• **Incineration and Open Burning of Waste**	√	√
➢ **Incineration**	√	√
➢ **Open Burning**	√	√
• **Wastewater Treatment and Discharge**	√	√
➢ **Domestic Wastewater**	√	√
➢ **Industrial Wastewater**	√	√
○ **Natural Rubber Latex & SMR**	√	√
○ **Palm Oil Mills – POME**	√	√
○ **Petroleum Refineries**	√	√
○ **Pulp & Paper**	√	√
○ **Meat & Poultry**	√	√

Note:
NA (not applicable) – activities in a given source/sink category which do not result in emissions or removals of a specific gas;
NE (not estimated) – existing emissions and removals which have not been estimated;
NO (not occurring) **–** activities or processes that do not occur for a particular gas or source/sink category within a country.

Efforts had also been taken to improve the accuracy and completeness of the whole GHG inventory time series.

For the energy sector sectoral approach estimations, recalculations were undertaken for the road transport and fugitive emissions from oil and natural gas sub-categories. In the National Energy Balance (NEB), information on gasoline and diesel usage was only available for the whole transport sector and past disaggregation of that data for road transport GHG emission estimation was based on expert judgement. In the current inventory, road transport GHG emission estimation was based on petrol (gasoline) and diesel sold at petrol stations nationwide where the data from 2017-2019 was made available by the ministry responsible for domestic trade. For the inventory years prior to 2017, the estimation was based on a ratio method based on the 2017-2019 petrol and diesel usage for road transport to total petrol and diesel usage for the transport sector reported in the NEB.

Recalculation for fugitive emissions from oil and gas was carried out based on the total amount of gas vented and flared from the oil and gas fields from 2012-2019 that was made available to the compilers by the Malaysia Petroleum Management. For the years prior to 2012, the activity data for amount of gas flared or vented was estimated based on the product of ratio of gas production in the year concerned and the average of the gas production from 2012-2014 and the amount vented or flared in the gas and oil fields. For all the other sub-categories under fugitive emission from oil and natural gas systems (apart from venting and flaring during production), the emission factor at the lower 10% of the default emission factor range of the developing countries in the 2006 IPCC Guidelines was used. This value was chosen based on discussion and information with PETRONAS that the fugitive emissions from their operations would be comparable to those of developed countries.

For the IPPU sector, emissions from ferroalloys production were estimated for 2017-2019 for the first time. Minor recalculations were also undertaken for ‘other process uses of carbonates’ from 2011-2016 to remove double counting and incorrect interpretation of the activity data for 2016.

For the agriculture sector a minor update was undertaken to take into account updates in animal population and correction of errors in reporting the GHG emission time series totals in the Technical Annex of BUR3.

For the LULUCF sector, recalculation was undertaken for forest land. This was due to improvement in the tracking of land-use change in the years 1994-1996 and 2015-2016, taking into account the 20 years period in land use transition. Recalculation for cropland category was also undertaken, where the total harvest for oil palm, rubber and cocoa had been updated, besides updating the total cultivated area for years 2011, 2012 and 2014 for cocoa.

For the waste sector, a minor update was undertaken for ‘solid waste disposal’ to correct the truncated value of 1.33 for CH_4/C that was used in the calculation in BUR3. The recycling rate was also updated for 2014-2016. For domestic wastewater treatment and discharge, an update was also undertaken for the time series to reflect the additional activity data made available by the sewerage services departments in the state of Sarawak and Sabah respectively.

2.5 Summary of Greenhouse Gas Emissions and Removals for 2019

This section provides a summary of the greenhouse gas emissions and removals for 2019.

2.5.1 Reference and Sectoral Approaches for Energy Sector

Comparison between the CO_2 emissions based on the Reference and Sectoral Approaches for the energy sector was undertaken. For 2019, the *Reference Approach* resulted in emissions of 239,553.42 Gg of CO_2 whereas the *Sectoral Approach* resulted in an emission of 234,858.00 Gg of CO_2 from fuel combustion activities and 4,600.25 Gg CO2 from fugitive emissions (Table 2.2). The percentage difference in emissions between the sectoral approach (fuel combustion activities) and reference approach was 1.96%.

2.5.2 Major Sources of Greenhouse Gas Emissions

The total GHG emission excluding LULUCF for 2019 was 330,358.21 Gg CO_2 eq. and the total GHG emission including LULUCF was 115,643.68 Gg CO_2 eq. (Table 2.2).

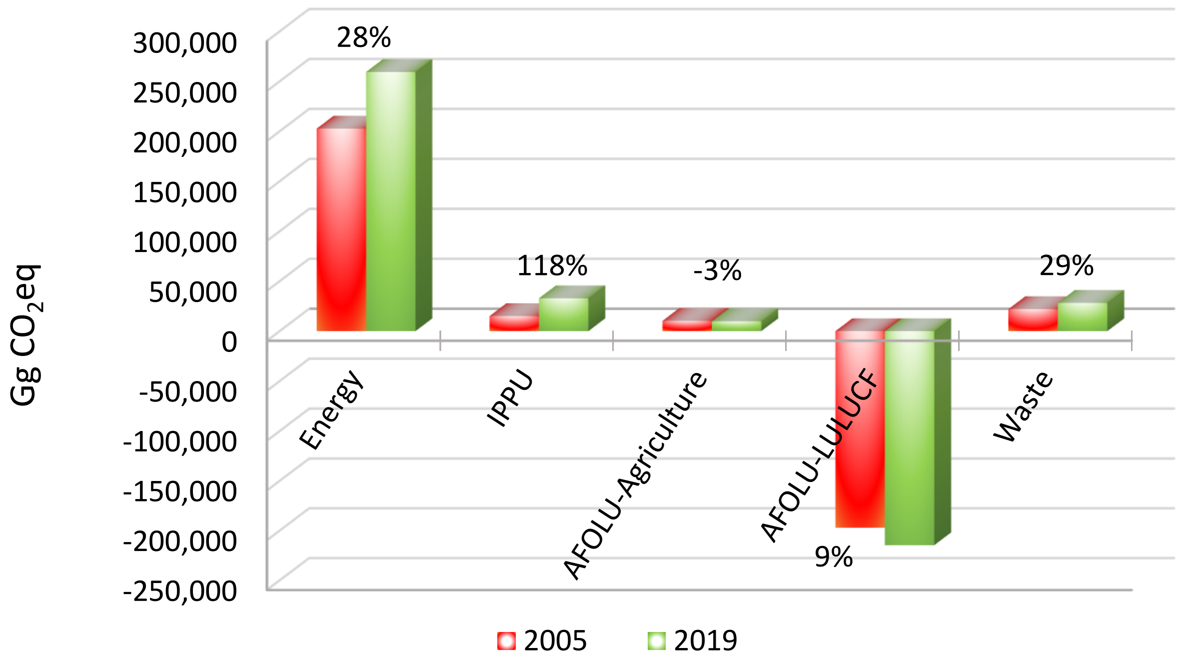
Table 2.2: Emissions and Removals of Greenhouse Gas for each Sector in 2019 using AR4 GWP

Sector		Emissions (Gg) A	AR4 GWPs B	CO_2 Equivalent (Gg) C=(A x B)
Energy Sector Reference Approach	CO_2	239,553.4202	1	239,553.42
Energy Sector Sectoral Approach	CO_2 (fuel combustion activities)	234,858.0038	1	234,858.00
	CO_2 (fugitive emissions)	4,600.2451	1	4,600.25
	CH_4	739.7520	25	18,493.80
	N_2O	4.6109	298	1,374.06
Sub-total				259,326.11
Industrial Processes and Product Use	CO_2	25,957.3497	1	25,957.35
	CH_4	14.0788	25	351.97
	N_2O	0.2016	298	60.07
	HFC-134a	0.65019180	1,430	929.77
	HFC-23 (CHF_3)	0.00295636	14,800	43.75
	PFC-14 (CF_4)	0.48894232	7,390	3,613.28
	PFC-116 (C_2F_6)	0.10904604	12,200	1,330.36
	PFC-218 (C_3F_8)	0.00369545	8,830	36.63
	SF_6	0.02121762	22,800	483.76
	NF_3	0.00295636	17,200	50.85
Sub-total				32,853.80
AFOLU – Agriculture*	CO_2	411.5667	1	411.57
	CH_4	162.0581	25	4,051.45
	N_2O	18.3178	298	5,458.69
Sub-total				9,921.71
AFOLU – LULUCF**	CO_2	-214,714.5400	1	-214,714.54
Sub-total				-214,714.54
Waste	CO_2	42.7700	1	42.77
	CH_4	1,113.3144	25	27,832.86
	N_2O	1.2784	298	380.96
Sub-total				28,256.59
Total Excluding AFOLU – LULUCF				330,358.21
Total Including AFOLU – LULUCF				115,643.68

Note: Negative values indicate sink.
- * IPCC Category 3A and 3C
- ** IPCC Category 3B

Emissions from the energy sector increased by 28%, IPPU sector by 118% and waste sector by 29% between the years 2005 and 2019. However, emissions from the AFOLU-Agriculture sector decreased by 3%, and AFOLU-LULUCF net removals increased by 9% over the same period (Figure 2.1).

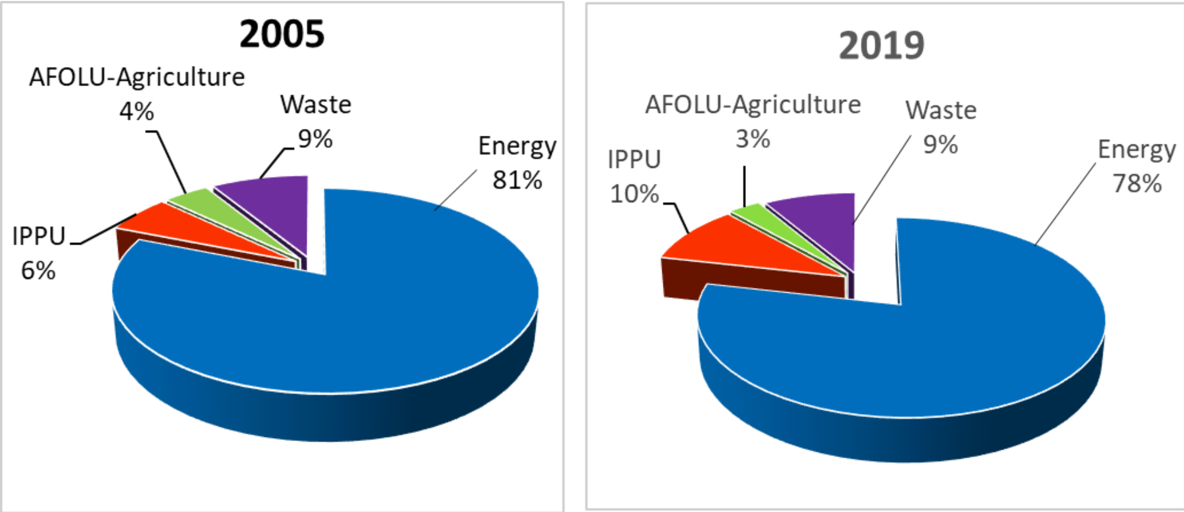
Figure 2.1: Comparison of Greenhouse Gas Emissions by Sector between 2005 and 2019



Note: Percentage indicates the % emission increase/decrease between 2005 and 2019.

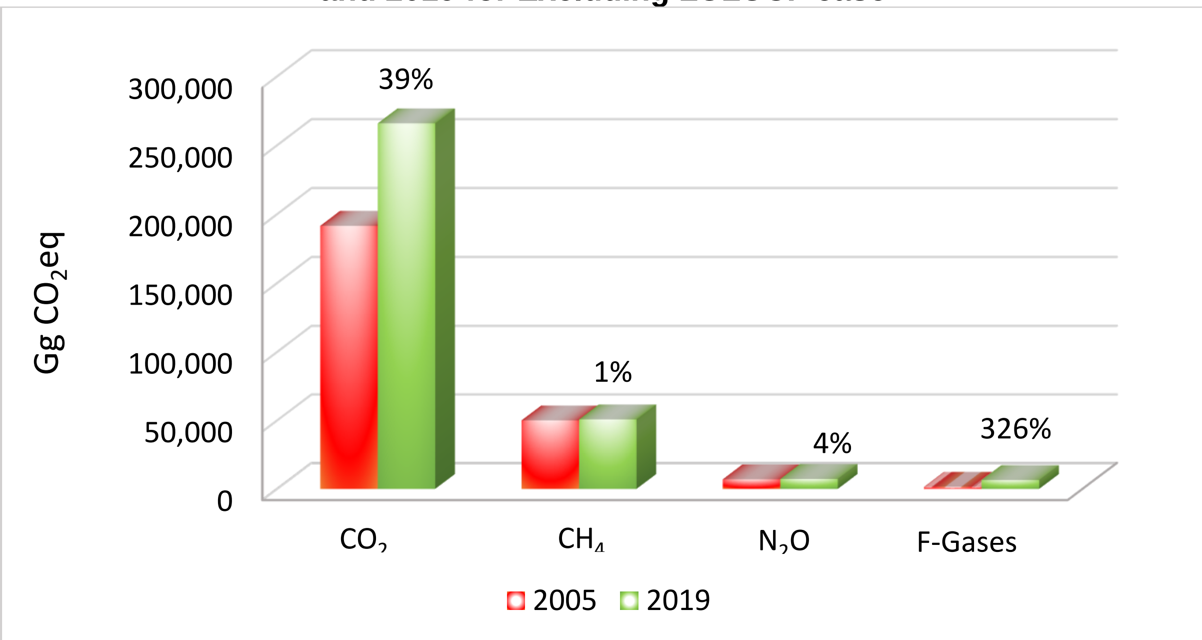
Excluding LULUCF, in 2019 the energy sector contributed 78% of the emissions, the IPPU sector 10%, the waste sector 9% and the agriculture sector 3%.

Figure 2.2: Percentage of GHG Emissions by Sector for 2005 and 2019 for Excluding LULUCF Case



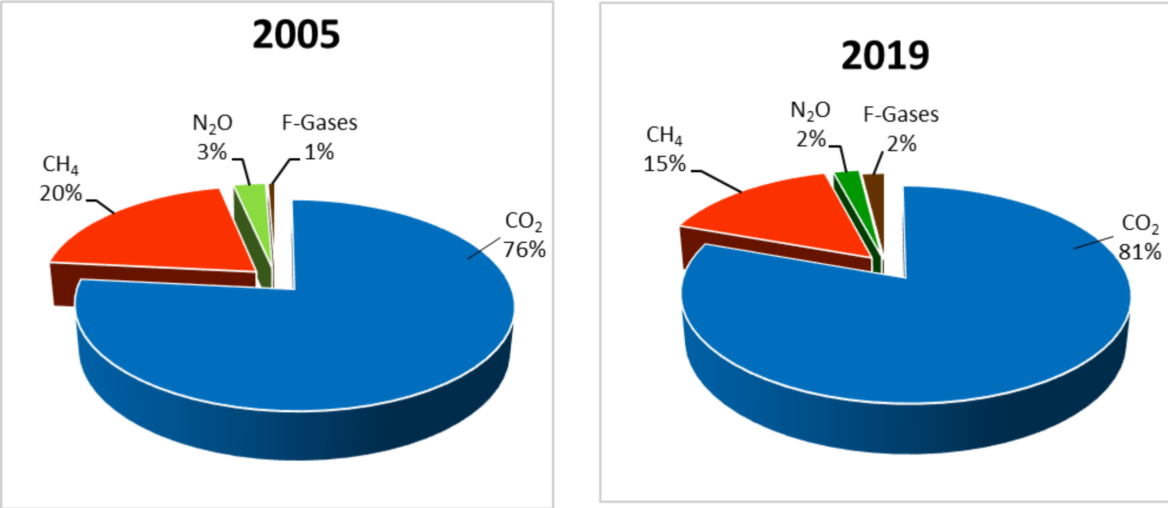
Excluding LULUCF, CO_2 emissions increased by 39%, CH_4 emissions by 1%, and N_2O by 4%. The F-gases emissions increased by 326%, however the emission amounts were small (Figure 2.3).

Figure 2.3: Comparison of Greenhouse Gas Emissions by Gas between 2005 and 2019 for Excluding LULUCF case



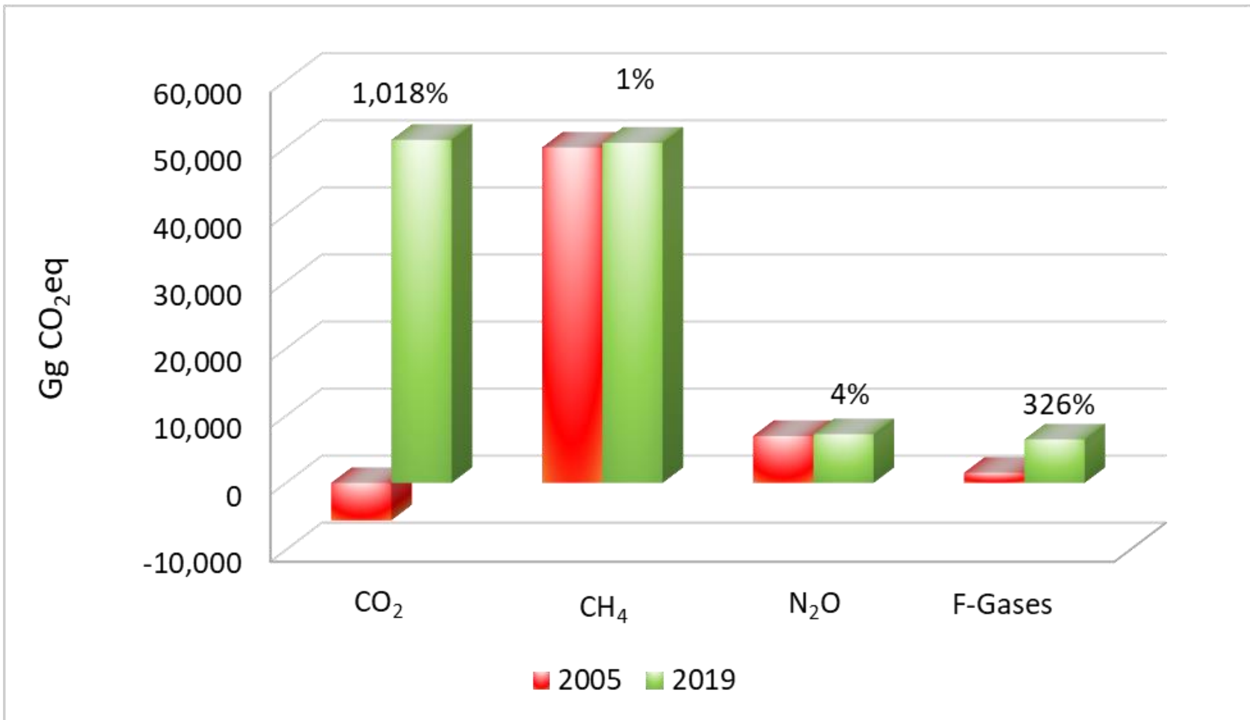
Excluding LULUCF, CO_2 emissions amounted to 81% and 76% of the total GHG emissions in 2019 and 2005 respectively (Figure 2.4) while CH_4 emissions were 15% and 20% of the total GHG emissions respectively for those years. N_2O emissions were at 2% and 3% of the total GHG emissions respectively and F-gases were at 2% and 1% of the total emissions respectively for those years.

Figure 2.4: Percentage of GHG Emissions by Gas for 2005 and 2019 for Excluding LULUCF case



Including LULUCF, CO_2 emissions grew by 1,018% between 2005 and 2019, however CH_4 emissions grew by only 1%, N_2O emission by 4% and F-gases by 326% (Figure 2.5).

Figure 2.5: Comparison of Greenhouse Gas Emissions by Gas between 2005 and 2019 for Including LULUCF case



2.5.3 Major Sources of Carbon Dioxide Emissions

In 2019, the CO_2 emission from electricity and heat production was the highest at 109,349.31 Gg CO_2 (36%), followed by emissions from road transport at 54,225.95 Gg CO_2, land converted to settlements at 40,854.94 Gg CO_2 (13%) (Figure 2.6). Manufacturing industries and construction's own energy generation was the fourth largest contributor to CO_2 emissions at 33,482.54 Gg CO_2 (11%).

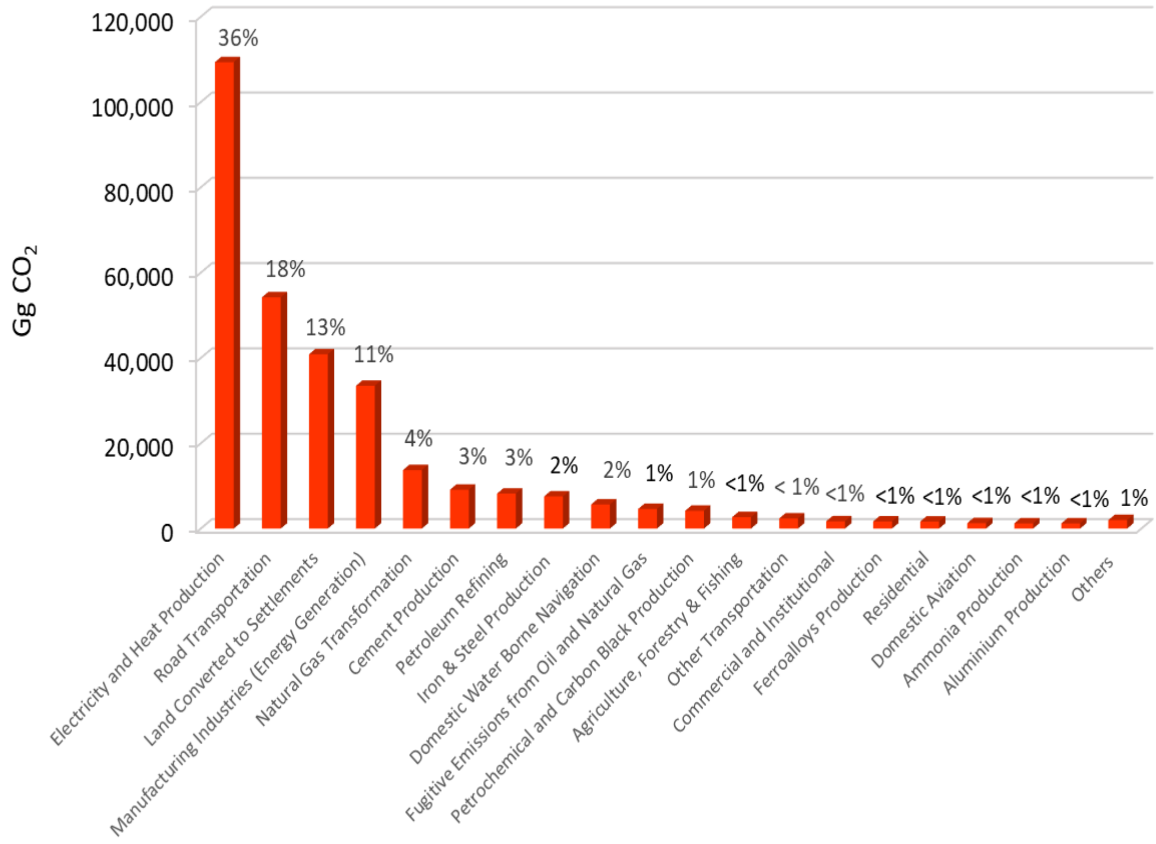


Figure 2.6: Major Sources of Carbon Dioxide Emissions in 2019 for Excluding LULUCF case

2.5.4 Major Sources of Methane Emissions

For 2019, a total of 50,730 Gg CO_2 eq. of methane was emitted (Figure 2.7). The highest emission was from fugitive emissions from the oil and gas industries, which accounted for 17,842 Gg CO_2 eq. (35%) of the methane emissions, followed by emissions from industrial waste water treatment and discharge amounting to 14,462 Gg CO_2 eq. (29%) and solid waste disposal sites at 11,681 Gg CO_2 eq. (23%). Over 99% of the emissions from industrial waste water treatment and discharge was from palm oil mill effluent (POME).

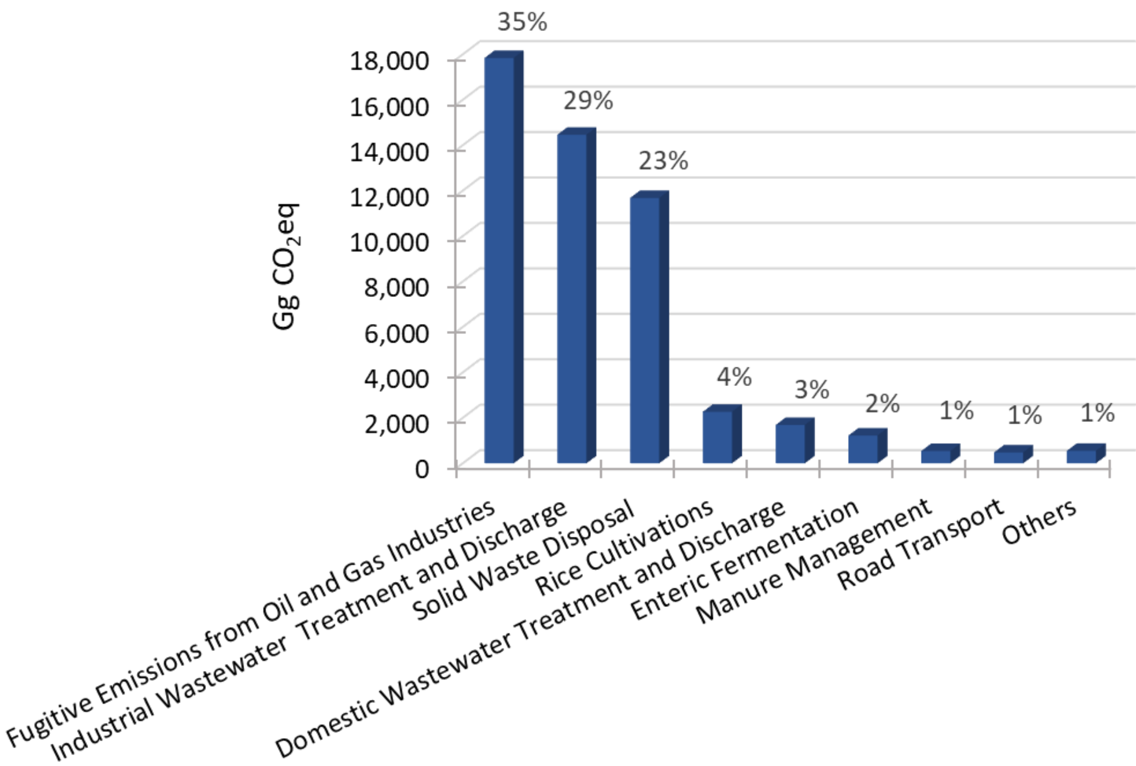


Figure 2.7: Major Sources of Methane Emissions in 2019

2.5.5 Major Sources of Nitrous Oxide Emissions

In 2019, a total of 7,274 Gg CO_2 eq. of N_2O were emitted. The emissions were primarily from the agriculture sector and energy sector (road transport and energy industries) as shown in Figure 2.8. The agriculture sector contributed about 75% of the total emissions, with emissions from direct and indirect N_2O from managed soil contributing nearly 66% of the emissions. Manure management contributed over 9% of the emissions. The energy sector contributed over 17% of the emissions with road transport contributed nearly 11% and energy industries contributed nearly 6% of the emissions.

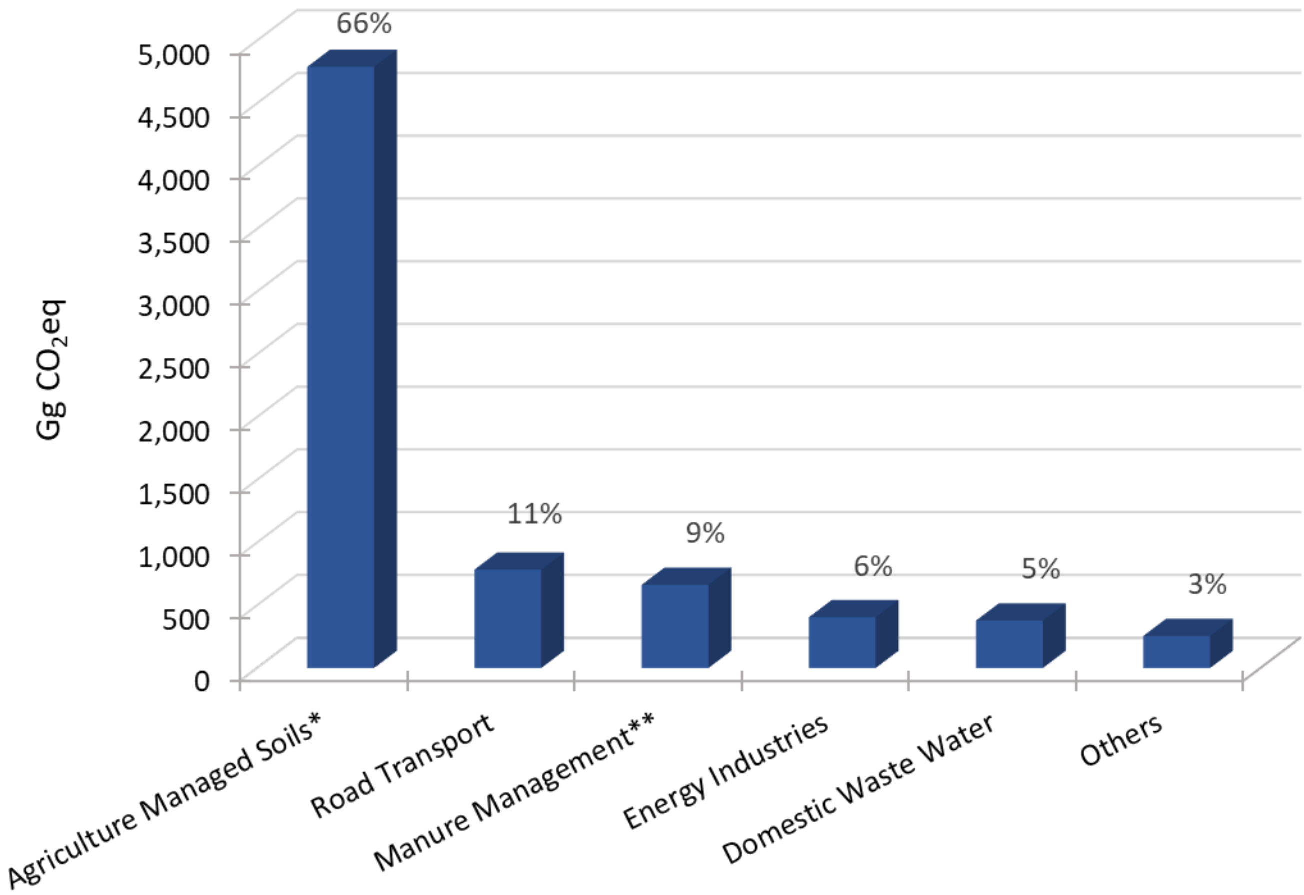


Figure 2.8: Major Sources of Nitrous Oxide Emissions in 2019

Note: * Included direct and indirect N_2O emissions from agriculture managed soils
** Included indirect N_2O emissions from manure management

2.6 Summary of GHG Emissions and Removals for 2005, 2017, 2018 and 2019

The GHG emission time series from 1990-2019 is shown in Figure 2.8. Excluding LULUCF, the energy sector was the main contributor to the emissions, accounting an average of annual emissions of 80.55% from 2005-2019. Overall, Malaysia's net emissions were a net sink from 1990 until 2004. From 2005 onwards the net emissions had increased from 52,967.03 Gg CO_2 eq. to 115,643.68 Gg CO_2 eq.

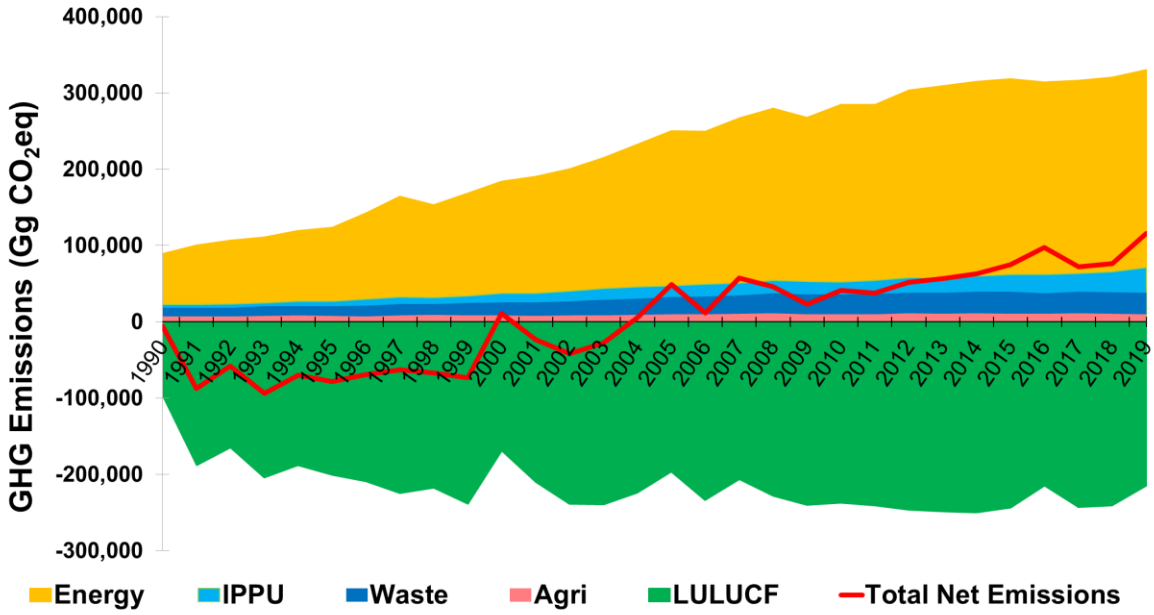


Figure 2.: GHG Emission Time Series from 1990 to 2019

A summary of the GHG emissions for the base year 2005 and for the years 2017, 2018 and 2019 is as shown in Table 2.3. The average net emissions from 2017-2019 was 89,479.90 Gg CO_2 eq.

Table 2.3: Summary of GHG Emissions for 2005, 2017, 2018 and 2019

Sector / Year	2005	2017	2018	2019
Energy	202,676.41	252,710.49	255,231.55	259,326.11
IPPU	15,101.60	24,203.62	26,697.07	32,853.80
AFOLU-Agriculture	10,265.04	11,063.54	10,690.29	9,921.71
AFOLU-LULUCF	-197,076.76	-243,369.73	-241,264.08	-214,714.54
Waste	22,000.75	28,585.40	28,247.87	28,256.59
Total Excluding LULUCF	250,043.80	316,563.05	320,866.78	330,358.21
Total Including LULUCF	52,967.03	73,193.32	79,602.70	115,643.68

2.7 Comparison of 2019 GHG Emissions between AR4 and AR5 GWPs

In this section, a comparison of the 2019 GHG Inventory by sector and by gas in CO_2 eq. values between using the 100-year time horizon global warming potential (GWP) values from the IPCC Fourth Assessment Report (AR4) and IPCC Fifth Assessment Report (AR5) is presented. Table 2.4 shows the AR4 and AR5 GWP values used for the comparison.

Table 2.4: Global Warming Potential Used

Gas	Chemical Formula	AR4 GWP	AR5 GWP
Carbon Dioxide	**CO_2**	**1**	**1**
Methane	**CH_4**	**25**	**28**
Nitrous oxide	**N_2O**	**298**	**265**
Hydrofluorocarbon	**HFC-134a**	**1,430**	**1,300**
Hydrofluorocarbon	**HFC-23 (CHF_3)**	**14,800**	**12,400**
Perfluorocarbon	**PFC-14 (CF_4)**	**7,390**	**6,630**
Perfluorocarbon	**PFC-116 (C_2F_6)**	**12,200**	**11,100**
Perfluorocarbon	**PFC-218 (C_3F_8)**	**8,830**	**8,900**
Sulphur hexafluoride	**SF_6**	**22,800**	**23,500**
Nitrogen trifluoride	**NF_3**	**17,200**	**16,100**

The total CO_2 eq. GHG emission is slightly higher using AR5 GWPs compared to using AR4 GWPs. Excluding LULUCF, the total 2019 GHG emission was 335,059.05 Gg CO_2 eq. using AR5 GWPs compared to 330,358.21 Gg CO2 eq. using AR4 GWPs, giving a difference of 1.42% (Table 2.5). Including LULUCF, the total 2019 GHG emission was 120,344.51 Gg CO_2 eq. using AR5 GWPs compared to 115,643.68 Gg CO_2 eq. using AR4 GWPs, giving a difference of 4.06%

By sector, the largest difference of 11.64% was observed in the waste sector due to the higher AR5 GWP value of 28 for methane (CH_4) compared to the AR4 GWP value of 25.

Table 2.5: Comparison of 2019 GHG Inventory by Sector Differences Between Using AR4 and AR5 GWPs

Sector	AR4 GWP	AR5 GWP	Percent Difference
Energy	259,326.11	261,393.21	0.80%
IPPU	32,853.80	32,318.08	-1.63%
AFOLU-Agriculture	9,921.71	9,803.41	-1.19%
AFOLU-LULUCF	-214,714.54	-214,714.54	0.00%
Waste	28,256.59	31,544.35	11.64%
Total Excluding LULUCF	330,358.21	335,059.05	1.42%
Total Including LULUCF	115,643.68	120,344.51	4.06%

Comparison by gas (Table 2.6) shows the 2019 GHG Inventory CO_2 eq. methane emissions to be higher by 12.0% using AR5 GWP compared to using AR4 GWP. The nitrous oxide and F-gases CO_2 eq. emissions were however 11.07% and 8.81% lower when using AR5 GWP compared to using AR4 GWP.

Table 2.6: Comparison of 2019 GHG Emissions by Gas Difference Between AR4 and AR5 GWPs

Gas	AR4 GWP	AR5 GWP	Percent Difference
CO_2 Excluding CO_2 From LULUCF	265,869.94	265,869.94	0.00%
CO_2 Including CO_2 From LULUCF	51,155.40	51,155.40	0.00%
CH_4	50,730.08	56,817.69	12.00%
N_2O	7,273.78	6,468.29	-11.07%
F-Gases	6,484.42	5,913.11	-8.81%
Total Excluding LULUCF	330,358.21	335,059.05	1.42%
Total Including LULUCF	115,643.68	120,344.51	4.06%

CHAPTER 3

3. MITIGATION ASSESSMENT

3.1 Introduction

Efforts continued to be taken by Malaysia to mainstream mitigation actions into its development through the development and implementation of polices, plans and programmes that have mitigation co-benefits which at the same time meets the development needs of the country. Specifically in the 12th Malaysia Plan (2021-2025), one of the main thrusts is on 'Advancing Green Growth to Enhance Environmental Sustainability'. There are three priority areas for this thrust and each priority area has respective strategies which are as follows:

i. Priority Area A – Implementing a Low-Carbon, Clean and Resilient Development
    - Strategy A1 – Moving Towards a Low-Carbon Nation
    - Strategy A2 – Accelerating Transition to the Circular Economy
    - Strategy A3 – Sharing Responsibility in Pollution Prevention
    - Strategy A4 – Increasing Resilience against Climate Change and Disasters

ii. Priority Area B – Managing Natural Resources Efficiently to Safeguard Natural Capital
    - Strategy B1 – Conserving Natural Ecosystems
    - Strategy B2 – Protecting and Conserving Species and Genetic Resources
    - Strategy B3 – Ensuring Sustainable Utilisation and Benefit Sharing
    - Strategy B4 – Enhancing Conservation of Water Resources

iii. Priority Area C – Strengthening the Enabling Environment for Effective Governance
    - Strategy C1 – Strengthening Environmental Governance
    - Strategy C2 – Scaling-up Green Financing and Investments
    - Strategy C3 – Instilling Sense of Ownership and Shared Responsibility

The emphasis to minimize GHG emissions are highlighted through the green growth implementation, energy efficiency enhancement and green mobility promotion initiatives in the 12th Malaysian Plan as well. The awareness of the need to accurately quantify mitigation actions and their effects is also increasing among the government agencies and the private sector.

Additional efforts however are required for Malaysia to meet the mitigation targets stated in the updated NDC submitted to the UNFCCC in July 2021. That pledge expressed Malaysia's commitment to reduce by 45% its GHG emissions per GDP by 2030, relative to its emissions intensity in 2005.

This chapter provides a summary of polices, plans and programmes in place to drive the mitigation agenda of the country as part of its sustainable development agenda.

An indicative GHG emissions modelling projection on possible mitigation pathways for Malaysia to fulfil its Paris Agreement target is also provided. The quantified *Mitigation Actions and Their Effects* are reported in the Fourth Biennial Update Report.

3.2 National Policy and Framework

A brief description of the updated national Policy and Planning Framework for mitigation is provided as below.

3.2.1 National Policy on Climate Change

The main policy to guide Government agencies, industry, communities and other stakeholders in addressing the challenges of climate change in an effective and holistic manner is provided in the National Policy on Climate Change approved by the Cabinet in 2009. The policy recognised the need for both mitigation and adaptation to be carried out in a balanced manner where national responses that consolidate economic, social and environmental development goals are mainstreamed based on the following five principles:

- *Development on a sustainable path*: To integrate climate change responses into national development plans to fulfil the country's aspiration for sustainable development;
- *Conservation of environment and natural resources*: To strengthen implementation of climate change actions that contribute to environmental conservation and sustainable use of natural resources;
- *Coordinated implementation*: To incorporate climate change considerations into the implementation of development programmes at all levels;
- *Effective participation*: To improve participation of stakeholders and major groups for effective implementation of climate change responses; and
- *Common but differentiated responsibilities and respective capabilities*: International involvement on climate change will be based on the principle of common but differentiated responsibilities and respective capabilities.

3.2.2 Sectoral Policies

The policies that give effect to mitigation are contained in sectoral polices related to the energy; transport; IPPU; waste; land use, land-use change and forestry; and agriculture sectors. These policies are implemented by the respective Ministries and their associated Agencies through the Malaysia Development Plans.

Table 3.1 summarises the major mitigation actions across those sectors and their related key policies. The practical targets of these mitigations are discussed in greater detail in the respective sections of the GHG emission projection section of this chapter.

Table 3.1: Major Mitigation Actions and Related Policies

Sector/ Sub-Sector	Mitigation Actions	Related Policies	Policy Target
Energy[1]			
Power Generation	Renewable Energy Initiatives	• National Renewable Energy Policy and Action Plan (NREPAP, 2011) • 12th Malaysia Plan	• The development and utilisation of renewable energy resources to be intensified to achieve the target of 31% RE of the total installed capacity for the whole of Malaysia (12th Malaysia Plan)
	Energy Efficiency	• National Energy Efficiency Action Plan (NEEAP, 2015) • Efficient Management of Electrical Energy Regulations (EMEER, 2008) • 12th Malaysia Plan	• 52,233 GWh of electricity savings over a 10-year period from 2016 to 2025, corresponding to an electricity demand growth reduction of 8% at end of the plan.
	Generation of power from coal power plant	• National Energy Policy, 1979 • Electricity Regulation, 1994 • Gas Supply Regulation, 1997	• Reduced share of installed capacity in the overall power generation capacity mix for Peninsular Malaysia from 42% in 2020 to 29% in 2030

[1]Energy policies developed from 2020 onwards especially the National Energy Transition Roadmap (NETR) that was developed in 2023 would only be reported in the first Biennial Transparency Report of Malaysia in 2024. Some of the targets in the National Energy Policy 2022-2040 were considered in the development of the projection.

Sector/ Sub-Sector	Mitigation Actions	Related Policies	Policy Target
		• Fuel Diversification Policy, 2001	(as per the Report on Peninsular Malaysia Generation Development Plan 2019 (2020 – 2030))
Transport	Electric Vehicles	• Low Carbon Mobility Blueprint 2021-2030	• 100,000 electric vehicles by 2030
	Biofuel Initiative	• National Biofuel Policy, 2006 • 12th Malaysia Plan	• Mandate of B10 (10% bio-diesel blending) starting from 2019.
Industries	Biofuel Initiative	• National Biofuel Policy, 2006 • 12th Malaysia Plan	• Mandate of B7 biodiesel starting from 2019.
Waste	• Waste Recycling	• National Solid Waste Management Policy (revised 2016) • 12th Malaysia Plan	• 40% recycling rate of household waste by 2025.
	• Methane Recovery from POME	• MPOB Mandatory Regulation (2014)	• Increase of biogas capture facilities
Agriculture	• Good Agriculture Practices	• National Agrofood Policy 2.0 (2021-2030) • National Agricommodity Policy 2021-2030 (DAKN 2030)	• Increase yield per hectare to optimise land use • Optimum use of fertilisers

Sector/ Sub-Sector	Mitigation Actions	Related Policies	Policy Target
Land Use, Land-Use Change and Forestry	• Sustainable Forest Management	• Malaysia Policy on Forestry • National Policy on Biological Diversity 2016-2025 • REDD Strategy	• At least 50% of Malaysia's land mass remains forested.

3.2.2.1 Energy Management and Conservation

In 2019 the power sector contributed 32% of the country's GHG emissions. Energy security and affordable electricity rates to consumers remain the main priorities of the country. Hence to a large extent, the energy mix for electricity generation is dictated by population affordability. Nevertheless, efforts are being taken to cap the share of coal in the energy mix. In addition, efforts continue to be taken to enhance the share of clean and green energy sources in its electricity generation and at the same time encouraging energy efficiency in its usage.

The National Energy Transition Roadmap (NETR) was recently launched in July 2023 with aims to power the future by unlocking potentials in new growth areas and delivering progress and prosperity to Malaysian households and businesses. The plan aspires to steer Malaysia's shift from traditional fossil fuels-based economy to a high-value green economy. The policies conducted and outlined in this plan will be reported in the first Biennial Transparency Report of Malaysia in 2024.

Apart from NETR, the Hydrogen Economy and Technology Roadmap (HETR) was also recently launched in October 2023 with the aims to achieve decarbonisation and to spearhead the hydrogen economy through the application of hydrogen and its derivatives. It is a living document for new industrial development propelled by the applicable technologies and innovations.

Renewable Energy

In the 12th Malaysia Plan, the development and utilisation of renewable energy will be intensified from 21.5% in 2019 to 31% by the end of the plan in 2025. The focus in the renewables include greater usage of biomass and biogas, apart from implementation of power generation from hydro and solar resources. The contribution of mitigation actions through the RE electricity from solar is estimated to increase through the increased installed capacity of renewable power sources. The adoption of new technologies comprising the energy storage system is planned to be promoted to address the intermittency issue in the renewable energy.

Energy Efficiency

A number of energy efficiency programmes had been reported since the first BUR. The newest of these is the National Energy Efficiency Action Plan which has been approved in 2016 for implementation. The NEEAP sets a target to save 52,233 GWh amount of electricity over a 10-year period from 2016 to 2025 that corresponds to an electricity demand growth reduction at the end of the plan of about 8.0%. These would be implemented through five initiatives namely,

Initiative 1: Promotion of 5-Star Rated Appliances;
Initiative 2: Minimum Energy Performance Standards (MEPS);
Initiative 3: Energy Audits and Energy Management in Buildings and Industries;
Initiative 4: Promotion of Co-generation; and
Initiative 5: Energy Efficient Building Design.

Through the implementation of NEEAP initiatives, GHG emissions are expected to be reduced.

3.2.2.2 Transport

The transport sector has been remained the second largest GHG emitting sector in the country based on the historical trend, accounting for 20% of the country's total GHG emissions in 2019. Of these 20%, about 17% comes from road transportation.

The National Transport Policy (NTP) 2019-2030 has been developed to lay the policy thrusts and strategies to enhance Malaysia's economic competitiveness, provide strong social impact particularly with respect to inclusivity and accessibility, while reducing the negative impact of the transport system on the environment. It provides an overarching policy to guide relevant federal ministries and agencies as well as State Governments and Local Authorities (PBT) to develop and streamline transport initiatives towards a common goal, resulting in effective and efficient use of resources.

Among the initiatives is to mainstream the shift towards electrification in the transportation industry as a key strategy to diminish our emissions and contribute towards the achievement of our national Paris Agreement GHG target. In the urban areas, especially in the Greater Kuala Lumpur Area, urban rail development had been implemented since the mid 1990's.

Continued implementation of the National Biofuel Policy has also resulted in higher blends of biodiesel being implemented for the transport sector. The B10 programme has been implemented since the year of 2019. While B20 biodiesel programme implementation is targeted to start in 2020 with phased nationwide rollout subject to infrastructure readiness, the B30 biodiesel blending target is to be implemented by 2030 especially for the heavy vehicles.

In the new National Industrial Master Plan 2030 (NIMP 2030) described below, the electric vehicle development is one of the four focusses in the master plan. It is also one of the four new growth areas identified in the NIMP 2030. There are plannings to install up to 10,000 charging stations to support the electric vehicle implementation in Malaysia. To achieve the target, the electric vehicle ecosystem and the supply chain will need to be strengthened.

3.2.2.3 Industrial Processes and Product Use

Prior to 2020, the development of industries in Malaysia was guided by the Third Industrial Master Plan 2006-2020. That policy guided Malaysia's long-term global competitiveness and innovation of the manufacturing and non-Government services sectors during that period. It covered 12 industries namely electrical and electronics, medical devices, textile and apparel, machinery and equipment, metals, transport equipment, petrochemicals, pharmaceuticals, wood-based, rubber based, oil-palm based and food processing. Success of the plan however had attracted investments in some high energy intensive and high GHG emitting sectors towards the end period of the plan.

NIMP 2030 was launched in September 2023. This policy aims to drive the next phase of the country's industrial development and advance its economic complexity, particularly in five key sectors: aerospace, digital economy, chemicals and petrochemicals, electrical and electronics, and pharmaceuticals. Among its missions is to push towards achieving net zero greenhouse gas emissions in the industrial sector through:

(i) accelerating transition towards sustainable practices in the industrial sector;
(ii) enhancing energy efficiency and use of renewable energy;
(iii) catalysing low carbon technologies and carbon capture as new growth areas;
(iv) advancing circular economy and industrial waste management; and
(v) shifting towards green infrastructure.

The plan would help to quicken early peaking of greenhouse gas emissions from the industrial sector and there after guide its greenhouse gas emissions reduction towards net zero as early as 2050.

The NIMP 2030 is a planning follow up to the New Investment Policy which was launched in October 2022. The New Investment Policy takes a comprehensive approach to catalyse high-quality investments to deliver forward-looking and equitable growth for the nation. One of the top line targets is sustained economic and wealth growth at 4.5-5.0% GDP growth per annum and GNI per capita growth at 5.5-6.0% per annum. It aspires to enhance environmental, social and corporate governance practices and de-risk the economy against these factors.

3.2.2.4 Waste Management

As stated in Chapter 2, without LULUCF, the waste sector contributed about 9% of the country's GHG emissions. The GHG emissions from this sector come mainly from methane emissions from solid waste disposal sites and from Palm Oil Mill Effluents (POME). The National Solid Waste Management Policy 2016 and the 12th Malaysia Plan (2021-2025) set a target of 40% recycling rate by 2025. The 12th Malaysia Plan also envisages that all seven types of waste (solid, sewage, scheduled waste, agriculture, construction and radioactive) shall be managed in a holistic manner based on a life-cycle approach, with increase investment to channel waste away from waste disposal sites to be used as a resource, either as input for other products or converted to energy. Such processes would help to reduce waste generation and contribute to GHG emissions reduction.

Reducing methane emissions from POME continues to be encouraged through *Developing Biogas Facilities at Palm Oil Mills.* Through this programme, palm oil mills are encouraged to install biogas trapping facilities to capture methane as fuel for their use or to generate electricity for sale to the national grid. In 2014 the Government mandated new palm oil mills and old mills that are expanding their capacity to install methane avoidance facilities. However, uptake has been slower than anticipated with only 130 facilities being installed by 2020.

3.2.2.5 Land Use, Land-Use Change and Forestry

The LULUCF sector plays an important role in Malaysia's action to address climate change. This sector remains a net sink while contributing to the nation's GDP. Hence it is necessary to continue to strengthen the sustainable forest management efforts of the country and enhance the forest reserves.

The management of all types of forests is enshrined in the Malaysia Policy on Forestry (MPF) or other relevant State Forests Policy. This policy provides greater uniformity in implementing strategies for achieving forest conservation, management, and social and educational needs. It represents an important policy framework, which is unequivocal in maintaining that forest management must fulfil environmental and conservational needs besides meeting rational economic production goals. It provides a reference, guidelines and strong emphasis on the necessity for sound management, conservation, utilisation, development and protection of the forests for the three regions namely Peninsular, Sabah and Sarawak. This commitment is duly recognised and given specific attention by the National Forestry Act 1984 (Amendment 2022) (NFA). In Sabah, the necessary legal backing is provided by the Sabah Forest Enactment 1968, Forest Rules 1969 and Forest (Timber) Enactment 2015 while in Sarawak the Sarawak' Forests Ordinance 2015 (Cap.71), provides the necessary legal framework.

To ensure sustainable forest management, a National Committee on Sustainable Forest Management in Malaysia comprising representatives from various agencies in the forestry sector was formed in 1994 to ensure that the International Tropical Timber Organisation's (ITTO) Criteria and Indicators on sustainable forest management are fully implemented. The standard used to asses Forest Management Units (FMUs) for the purpose of certification is the MC&I Standard of Performance for Forest Management [MC&I (2001)] which is based on the 1998 ITTO Criteria and Indicator for Sustainable Management of Natural Tropical Forest. The key elements for sustainable forest management would cover economic, social, environmental and conservational aspects.

To ensure sustainable harvesting of timber, a forest certification scheme was started from 2002 with the adoption of the Malaysian Criteria and Indicators (MC&I) for Sustainable Forest Management (SFM) certification. The maximum cutting limit has been capped at 85 m^3/ha. The Malaysian Timber Certification Council was established in October 1998 as an independent organisation to develop and operate the Malaysian Timber Certification Scheme (MTCS). The MTCS provides for independent assessment of forest management practices, to ensure the sustainable management of Malaysia's natural forest as well as to meet the demand for certified timber products. For 2020, a total of 5,139,745.36 ha of natural forests and 132,989.48 ha of forest plantations have been certified under the MTCS Programme for the Endorsement of Forest Certification (PEFC) Scheme.

Under the 11th Malaysia Plan (2016-2020), efforts were taken on forest enrichment to improve degraded forests. Programmes such as the Central Forest Spine in Peninsular Malaysia and the Heart of Borneo programme in Sabah and Sarawak serve as enablers to enhance connectivity between forests, reduce fragmentation and at the same time improve natural resource management. This is continued in the 12th Malaysia Plan, (2021-2025) where the government has committed to ‘Advancing Green Growth for Sustainability and Resilience’. In the main ’Game Changers’, reducing dependency on natural resources and maintaining at least 50% forest cover has been listed as one of its targets.

A REDD plus Strategy has been developed and adopted in 2017. The Strategy outlines policy actions to ensure at least 50% of Malaysia’s land mass remains as forest. This is achieved through enhancing sustainable forest management, conservation activities and seeking synergies with activities under the National Policy on Biological Diversity 2016-2025.

Table 3.2: Major Mitigation Actions and Related Policies

Sector/Sub-Sector	Mitigation Actions	Related Policies	Policy Target
Land Use, Land-Use Change and Forestry	● Reduced deforestation ● Sustainable Forest Management	● Malaysia Policy on Forestry ● National Policy on Biological Diversity ● REDD Strategy	At least 50% of Malaysia’s land mass remains as forest.

3.2.2.6 Agriculture

The development of the agriculture sector in Malaysia is guided by the National Agrofood Policy 2021—2030 (NAP2.0) and the National Agricommodity Policy (2021-2030), which respectively aim to increase food production and exports of industrial commodities. The objectives of the National Agrofood Policy are to ensure food security and that the food produced is safe to eat; to make the agro-food industry competitive and sustainable; and to increase the agro-based entrepreneur’s level of income.

Without LULUCF, agriculture accounts for 3% of Malaysia’s GHG emissions in 2019. Synthetic fertiliser usage accounts for about 31.6% of these emissions and efforts are being made to optimise fertiliser application.

Two certification schemes guide sustainable agriculture implementation in Malaysia. The Malaysian Good Agricultural Practices (MyGAP) launched in 2013 is a comprehensive certification scheme for the agricultural, aquaculture and livestock sectors. The Malaysian Organic Scheme (currently known as MyOrganic) launched in

2007 is a certification programme to recognise organically cultivated farms which do not use chemical pesticides and synthetic fertilisers.

For the commodity crops, increase of exports is to be met by increase in yield per hectare. Oil palm is the largest of these commodity crops and both the upstream and downstream activities of this sector are being improved to address land use competition. As of 2019, about 5.90 million ha were planted with oil palm in Malaysia and the maximum arable land for this crop is estimated at 6.5 million ha in 2020. The anticipated increase in global demand for vegetable oil will be met through increased oil yield per hectare. The National Agricommodity Policy and Action Plan 2021-2030 targeted an increase of average oil yield of 3.47 tonnes per hectare in 2019 to 3.70 tonnes per hectare by 2025 and 4.0 tonnes per hectare by 2030. The average fresh fruit bunch (FFB) yield is targeted to increase from 17.19 tonnes per hectare in 2019 to 18.25 tonnes per hectare by 2025 and 19.5 tonnes per hectare per year by 2030. Environmental performance regulations and sustainability criteria are complied with through the Malaysian Sustainable Palm Oil (MSPO), Roundtable on Sustainable Palm Oil (RSPO) and other sustainability certification schemes. Currently, all big oil palm plantations are MSPO or RSPO certified to ensure environmental sustainability. The National Agricommodity Policy 2021-2030 targeted all oil palm plantations to be MSPO certified by 2030.

3.2.3 Malaysia Development Plans

The ambition of the sectoral polices described in sections are operationalised through the five-year Malaysia Development Plans. Due to competing needs of the different areas, implementation is dependent on the availability of development funds which is tied to the economic growth during the period.

It is useful to note that the 11th Malaysia Plan provides the supports to address climate change through the emphasizing of sustainability. The 12th Malaysia Plan (2021-2025) described in the introduction takes these efforts further by having the strategic priority areas and the supporting initiatives. The fundamental shift is towards a development model that views resilient, low-carbon, resource-efficient and socially inclusive development as an investment that will yield future gains. The 12th Malaysia Plan (2021-2025) had set advancing sustainability as one of its three themes. Driving decarbonisation of the energy sector through greater deployment of renewable energy is one of the focusses.

3.3 GHG Emission Projection

This section presents an assessment on Malaysia’s GHG emission projection. The assessment had been carried out for the period from 2020 until 2030 for the five sectors namely Energy, IPPU, Waste, Agriculture and LULUCF. Three key scenarios have been explored in the assessment. In the *Without Measures* (WOM) scenario, the GHG emissions are projected based on a “no additional policy intervention” criterion. The *With Existing Measures* (WEM) scenario takes into account the existing policies and planned initiatives in 2019 that would be implemented until 2030. The *With Additional Measures* (WAM) scenario looks at potential emissions reduction when additional mitigation measures are implemented.

3.3.1 GHG Emission Projection Assumptions

The assumptions applied include the applicable sectoral and population growths are based on the pre-COVID-19 condition. The projection for the WOM scenario used population information as the Table 3.3 and GDP growth is based on the assumptions as the Table 3.4.

Key Note:
The COVID-19 pandemic, which started in the end of 2019 and relatively ended in 2022 is estimated to cause a decrease of energy demand due to domestic lockdown which contributes to a lower value of energy supply. During the preparation works of NC4, actual energy data for the year of 2020 was still in the process of publication by the related agency. Hence, the projection for the year of 2020 and onwards is based on the pre-COVID-19 condition assumptions. The updates pertaining to the actual energy data for 2020 and 2021 as well a relatively updated projection will be reported in the next reporting document e.g. the First Biennial Transparency Report (BTR1).

Table 3.3: Annual Population Growth Rate from 2020 to 2030

Year	2020-2030*
Average Population Growth Rate (% per annum)	1.1

*Projected values.

Table 3.4: Annual Growth Rate of GDP by Economic Activity from 2020 to 2030

Annual Growth Rate (%)	2020-2030*
Agriculture	1.0
Mining & Quarrying	Less than 0.1
Manufacturing	4.8
Construction	4.7
Services	8.0
Total GDP	4.5

*Projected and derived values from DOSM's Information on GDP based on the Type of Economic Activity

The macroeconomics projections up to 2030 are then used to generate energy demand functions using the regression software Microfit[2]. The energy demand functions generated then is used to estimate the final energy demand and supply projections and GHG emissions for the energy sector.

3.3.2 Summary of GHG Emission Projection Results

The projection indicates that the total emissions without LULUCF for Malaysia would be 481,363 Gg CO_2 eq for the WOM case by 2030 (Figure 3.1 and Table 3.5). Continued implementation of the planned activities under the WEM scenario would bring the emissions down to 367,603 Gg CO_2 eq. If further mitigation activities under the WAM scenario are carried out, the GHG emissions could reduce to 337,554 Gg CO_2 eq. The mitigation assumptions for each of the scenarios and sectors are described in section 3.3.3.

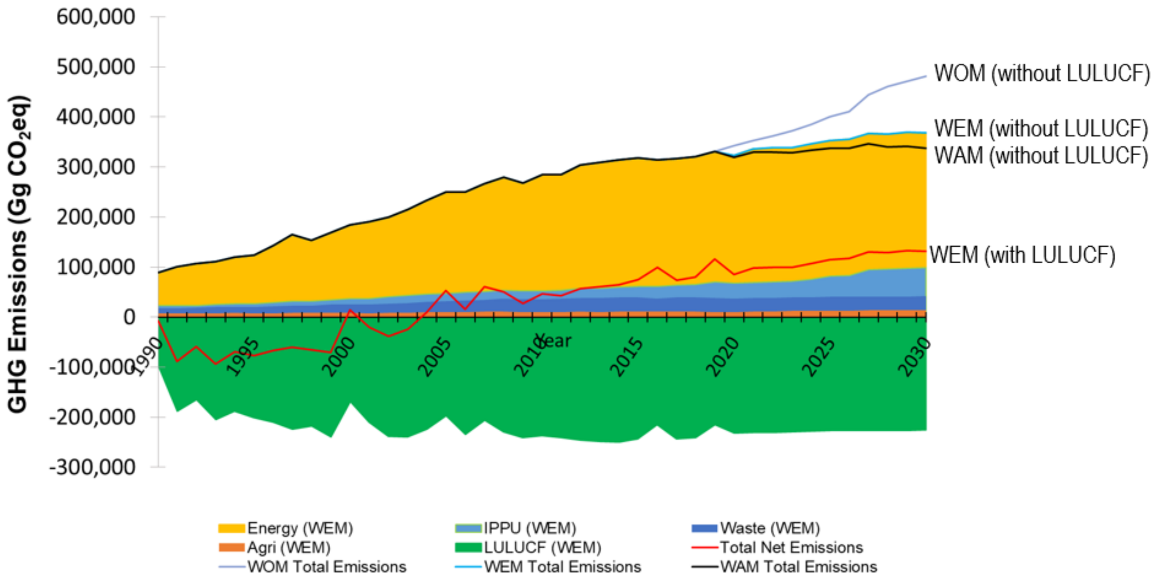


Figure 3.1: Projected Greenhouse Gas Emission Time Series for WOM, WEM and WAM Scenarios

The energy sector is projected to continue to be the largest contributor of GHG emissions in 2030 followed by the IPPU and waste sectors. For the WEM scenario without LULUCF, the GHG emissions from the energy sector is likely to be 80% of the total emissions in 2030. This is followed by the IPPU sector at around 11%, the waste sector at about 6% and the agriculture sector at 3%. For the WAM scenario without LULUCF, the energy sector is likely to account for 78% of the emissions in 2030. This is followed by the IPPU sector at 13%, the waste sector at 7% and the agriculture sector at 3%.

[2] Microfit is an econometric software to generate the demand equations for each of the fuels and sectors.

Table 3.5: Projected GHG Emissions by Sector under WOM, WEM and WAM Mitigation Scenarios in 2020, 2025 and 2030 (Gg CO_2eq)

Sector	2020			2025			2030		
	WOM	WEM	WAM	WOM	WEM	WAM	WOM	WEM	WAM
Energy	273,416	255,910	253,052	310,616	270,722	260,282	348,550	269,308	248,515
Industrial Processes and Product Use (IPPU)	31,385	30,304	29,007	44,285	41,715	38,365	82,462	56,585	50,662
Agriculture	10,499	10,499	10,065	14,829	13,070	11,285	16,257	13,615	11,310
Waste	27,768	26,987	26,987	30,612	27,392	26,829	34,094	28,095	27,067
Land Use, Land-Use Change and Forestry (LULUCF)	-227,480	-231,615	-233,145	-220,933	-227,121	-229,635	-220,931	-225,720	-232,236
Total emissions without LULUCF	343,008	323,677	319,088	400,343	352,903	336,761	481,362	367,603	337,553
Total emissions with LULUCF	115,528	92,062	85,943	179,410	125,782	107,126	260,431	141,883	105,317

3.3.3 GHG Emission Projection Assessment for Each Sector

3.3.3.1 Energy Sector

Table 3.6 summarizes the assumptions for the energy sector mitigation actions for the three aforementioned mitigation scenarios, WOM, WEM and WAM. Some of the mitigation actions listed in the table for the WEM and WAM scenarios are lower in target compared to the policy aspirations in Table 3.1 due to financial and technical limitations in implementing those targets. These more realistic targets adopted for the WEM scenario and WAM scenario were derived after consultation with the implementing Ministries and Agencies.

Table 3.6: Summary of Actions by Mitigation Scenarios for the Energy Sector

Mitigation Action	WOM Scenario	WEM Scenario	WAM Scenario
Renewable Energy Initiatives	No additional RE installations from 2019 onwards, with the capacity mix of hydro at 8 % and other RE at 9 % for Peninsular Malaysia. For Sarawak, the hydro power capacity remains at 3,458 MW	By 2030, RE installed capacity for Peninsular Malaysia increased to 30 % share of total installed capacity. Hydro power capacity in Sarawak increased to for Sarawak at 4,743 MW	By 2030, RE installed capacity for Peninsular Malaysia increased to 30 % share of total installed capacity. Hydro power capacity in Sarawak increased to for Sarawak at 4,743 MW
Generation of power from coal power plant	Continuous dependency on coal Installed capacity of coal power plants remained at 43 % from 2019 onwards for Peninsular Malaysia	Reduced dependency on coal. Installed capacity of coal power plants reduced to 29 % in 2030 for Peninsular Malaysia.	Enhanced reduced dependency on coal. Installed capacity of coal power plants reduced to 29 % in 2030 for Peninsular Malaysia.
Energy Efficiency Initiatives in Electricity Consumption	Energy savings from 2019 to 2025 based on NEEAP policy implementation and no further increase of energy savings from 2026 onwards	Energy savings from 2019 to 2025 based on NEEAP policy implementation and further improvement of 0.5 % energy savings per year from 2026 onwards.	Enhanced energy savings from 2019 to 2025 based on NEEAP policy implementation and further improvement of 1.0 % energy savings per year from 2026 onwards.
Fuel Shifting Initiative in Industry Sector	Introduction of B7 biodiesel for the industrial sector from 2019 onwards.	Mandate on B7 biodiesel in the industrial sector from 2019 onwards.	Mandate on B7 biodiesel in the industrial from 2019 onwards;

Mitigation Action	WOM Scenario	WEM Scenario	WAM Scenario
			Usage of biomass and biogas as alternative fuel.
Energy Efficiency Initiatives in Fuel Consumption	No improvements in technology.	Assume technology improvements for heating lead to 0.5% improvement in energy usage in commercial and industrial sectors by 2030.	Assume technology improvements for heating lead to 1% improvement in energy usage in commercial and industrial sectors by 2030.
Electric Vehicles	Assume no introduction of electric vehicles.	Assume progressive introduction of electrical vehicles to achieve total of 20,000 electric vehicles in 2030	Assume 100,000 electric cars and 100,000 electric motorcycles on-the-road by 2030
Biofuel Initiative (Reduce diesel dependence and emissions by blending petroleum diesel with biodiesel)	Mandate on B7 biodiesel in the transportation sector from 2014 onwards and no further change in biodiesel blending.	Mandate on B7 biodiesel in the transportation sector from 2014 onwards and improve to B10 from 2019 onwards.	Mandate on B7 biodiesel in the transportation sector from 2014 onwards and improve to B10 from 2019 and B20 from 2020 onwards.
Improvement in Natural Gas Transformation	No new policies are introduced to encourage energy efficient practices.	Improvement of 1% in plant operations and plant energy efficiency.	Improvement of 2% in plant operations and plant energy efficiency, plus introduction of carbon capture technology.
Improvement in Oil Refining Industries	No new policies are introduced to encourage energy efficient practices.	Improvement of 1% in plant operations and plant energy efficiency.	Improvement of 2% in plant operations and plant energy efficiency, plus introduction of carbon capture technology.

Mitigation Action	WOM Scenario	WEM Scenario	WAM Scenario
Reduction of Fugitive Emissions	No new policies are introduced to encourage fugitive emission reduction	Reduced routine flaring by 2030 and 25% methane emission reduction in natural gas supply chain by 2030	Zero routine flaring by 2030 and 50% methane emission reduction in natural gas supply chain by 2030

In all the three mitigation scenarios, the energy demand is projected to continue to grow in tandem with the increasing population and GDP. The modelling results indicate that energy demand will grow from 68.9 Mtoe[3] in 2020 to 90.7 Mtoe in 2030 in the WOM scenario and from 68.5 Mtoe in 2020 to 90.5 Mtoe by 2030 for the WEM scenario. For WAM scenario, the energy demand in 2020 and 2030 will be 68.0 Mtoe and 89.8 Mtoe respectively (Figure 3.2). The results indicate that more aggressive energy efficiency programmes across the sectors need to be put in place to reduce the demand.

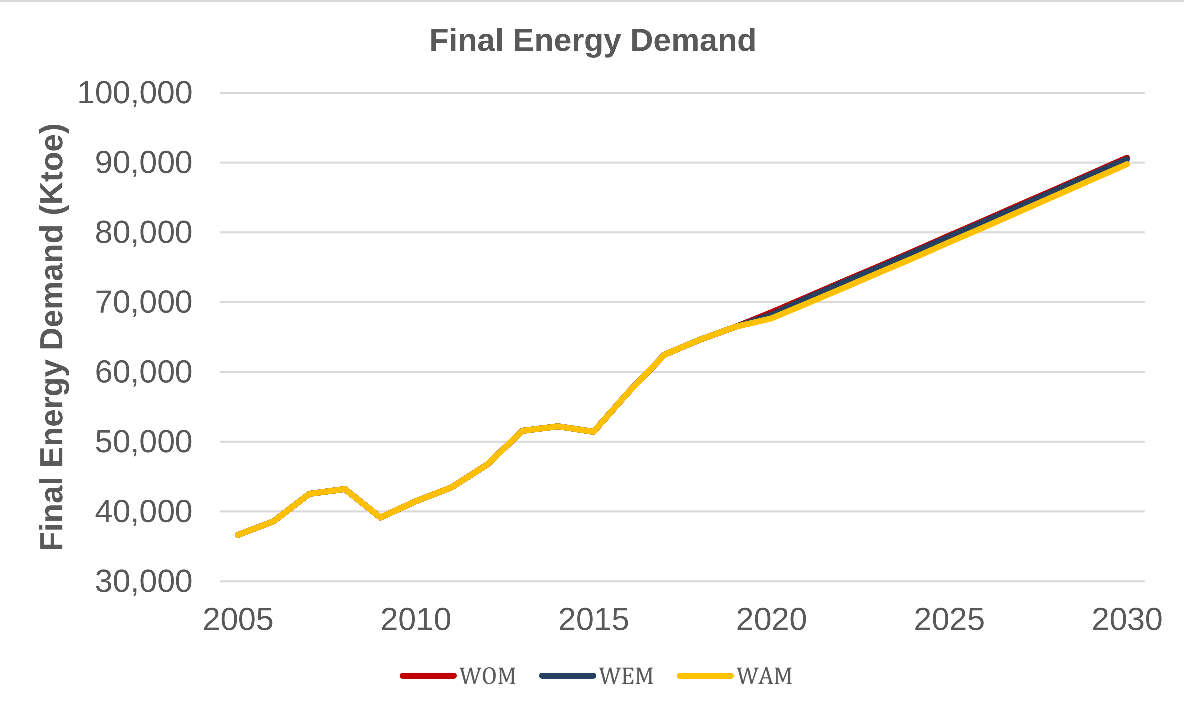
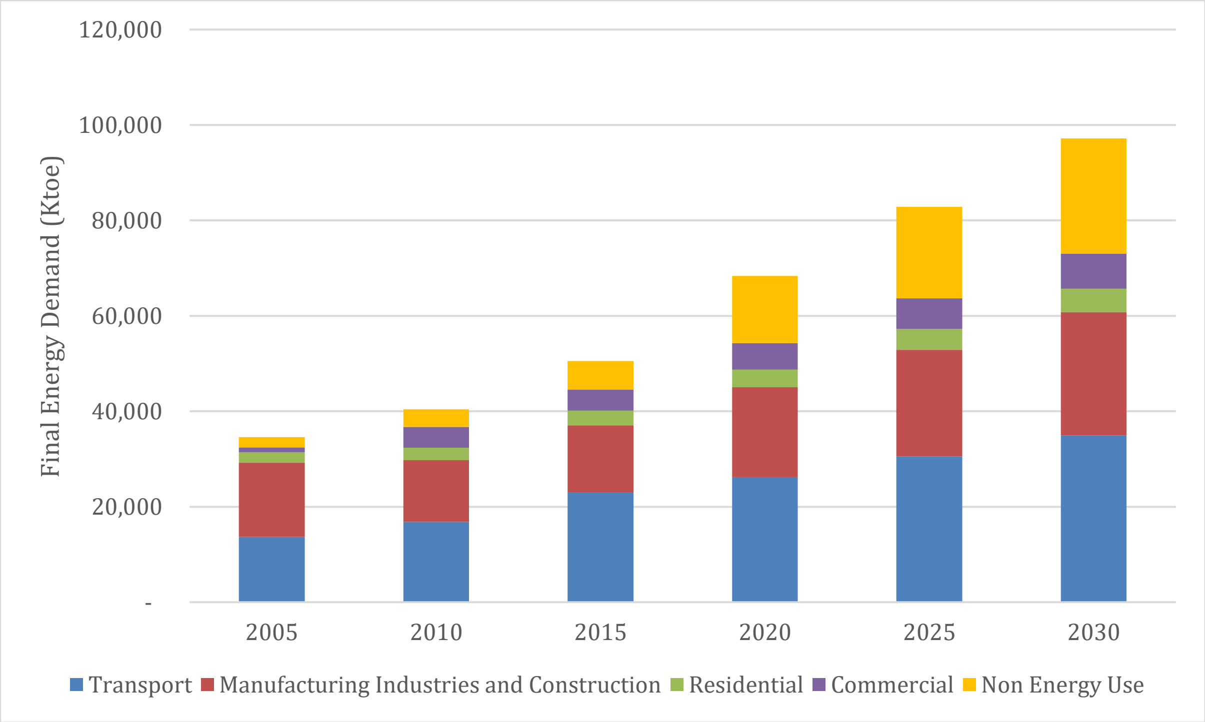


Figure 3.2: Final Energy Demand by Mitigation Scenarios from 2005 to 2030

In-depth analysis of the final energy demand by the different sub-sectors under the three scenarios showed that transport sector will continue to be the highest energy consumer up to 2030, followed by manufacturing industries and construction (Figure 3.3). Together these two sub-sectors are expected to account for 63% of energy demand in 2030, with the transport and manufacturing industries and construction sectors accounting for about 36 % and 27 % of the energy demand respectively in

[3] Energy demand value excluded fuel used for international civil aviation and international water borne navigation.

2030 for WEM scenario. In the WAM scenario, both sectors also provide the similar share of percentage in 2030 with the breakdown is roughly 36 % and 26 % each.



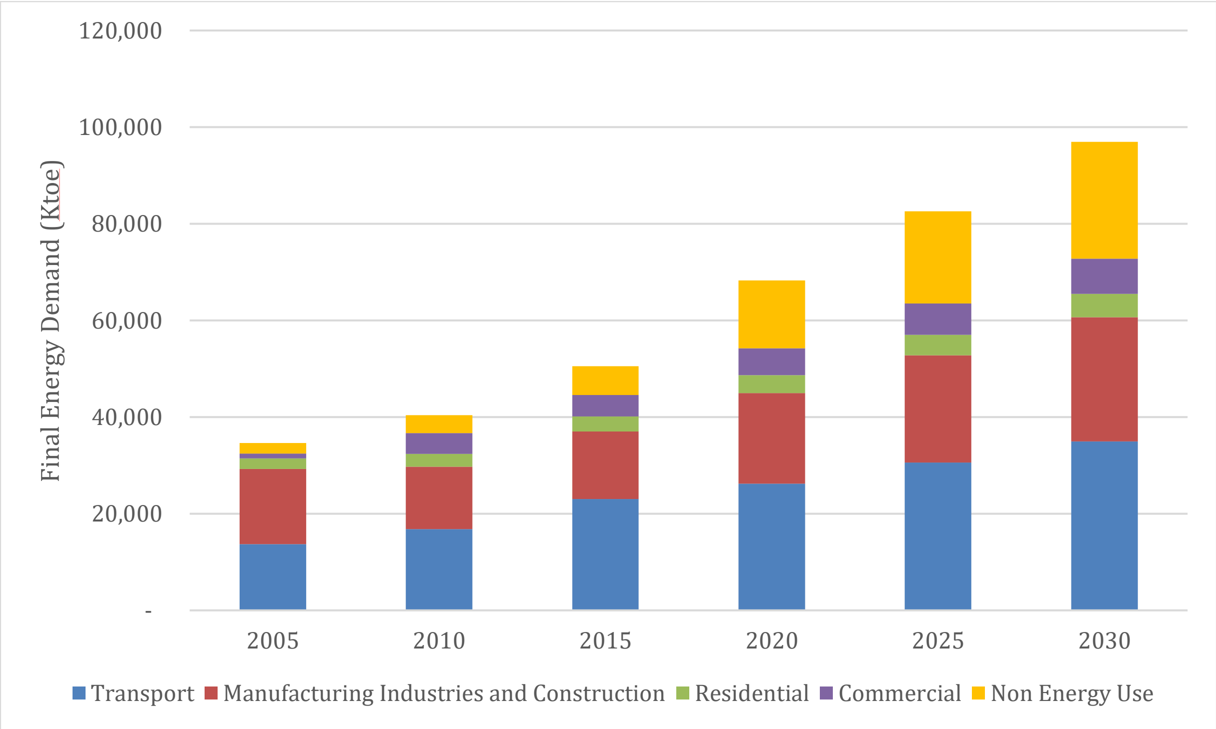


Figure 3.3: Final Energy Demand by Sub-Sectors under WEM (Top Diagram) and WAM (Bottom Diagram) Scenarios from 2020 to 2030

In tandem with the growth in energy demand, the GHG emissions for the energy sector for WOM scenario will also to grow over the projected time period (Figure 3.4). However, the GHG emission for the WEM and WAM scenarios will be relatively lower than WOM due to the effects of the aforementioned mitigation measures in the WEM and WAM scenarios.

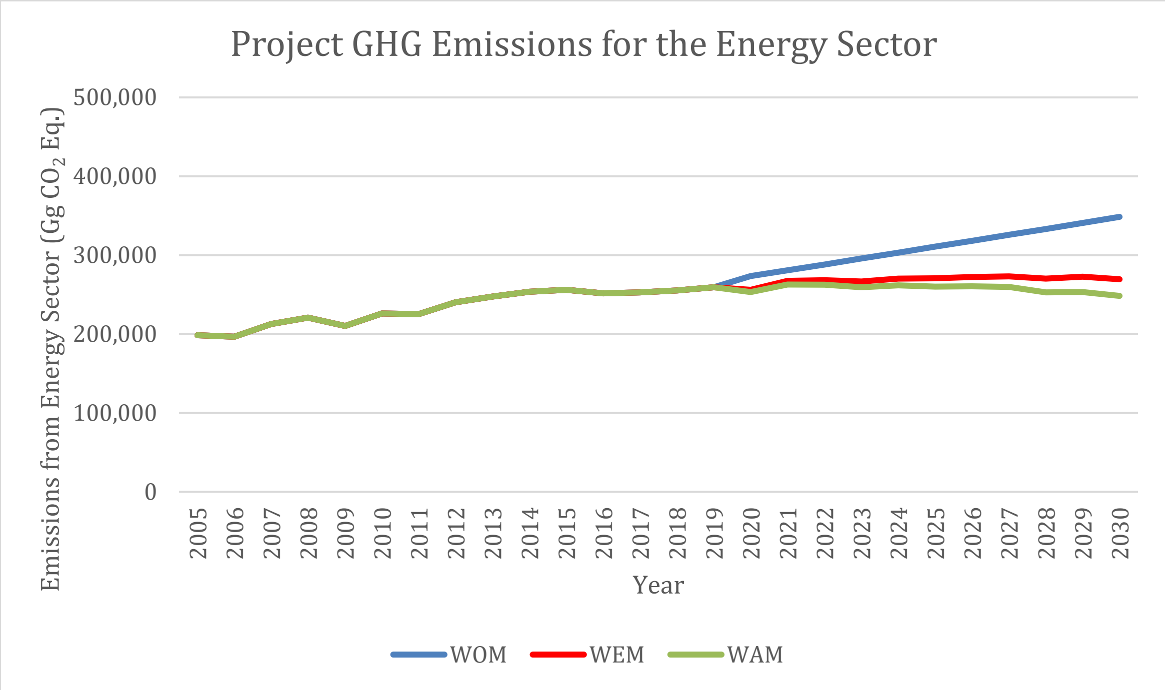


Figure 3.4: Projected GHG Emissions for the Energy Sector for WOM, WEM and WAM Scenarios

The WOM scenario is projected to have the highest GHG emission growth rate from among the three scenarios, with an annual growth rate of 2.5% from 2020 to 2030. Under the WEM scenario, where existing mitigation policies are implemented, the emissions are expected to be reduced by 6.4% (17,506 Gg CO_2 eq) by 2020 and up to 22.7% (79,242 Gg CO_2 eq) by 2030, relative to the WOM scenario. Further emission reductions are anticipated in the WAM scenario i.e. by 6.4% (18,043 Gg CO_2 eq) from the WOM scenario by 2020 and 28.7% (100,035 Gg CO_2 eq) by 2030.

Analysis of the projected GHG emissions for each of the energy sub-sectors (Table 3.6) indicates that GHG emissions from the electricity sector would continue to be the largest emitter. However, the magnitude of GHG emission is estimated to be reduced in both WEM and WAM scenarios. In the WEM scenario, the GHG emissions will decrease from 101,206 Gg CO_2 eq in 2020 to 98,657 Gg CO_2 eq in 2030. For the WAM scenario, GHG emissions is estimated at 100,622 CO_2 eq and 91,442 CO_2 eq in 2020 and 2030 each. These results indicate that increase of RE capacity in power generation and energy efficiency initiatives are necessary to help reduce emissions from this sub-sector.

The largest increase in GHG emissions in the energy sector comes from the manufacturing industries and construction sub-sector, increasing from 35,416 Gg CO_2

eq in 2020 to 55,580 CO_2eq in 2030 for the WEM scenario. In 2020 and 2030, the value of estimated GHG emissions is 35,391 and 55,544 CO_2 eq respectively under the WAM scenario. These increases will require further effort to reduce the GHG emissions of the manufacturing industries and construction sub-sector through certain initiatives and policies while supporting the competitiveness of the industry.

The second largest increase in projected GHG emissions is from the transportation sub-sector, increasing from 63,382 Gg CO_2 eq in 2020 to 66,334 Gg CO_2eq in 2030 for WEM scenario and from 62,104 Gg CO_2 eq to 64,473 Gg CO_2 eq in 2030 under WAM scenario.

In the projections, the GHG emissions from the natural gas transformation GHG for WOM scenario are assumed to remain around the range of the 2019 values for the projection period. The GHG emissions reduction projected for the WEM and WAM scenarios are based on the mitigation actions mentioned in Table 3.6. For the fugitive emissions from the oil and gas industry, the mitigation actions for reduction are shown in Table 3.7.

Table 3.7: Projected GHG Emissions for the Energy Sector under WOM, WEM and WAM Mitigation Scenarios in 2020, 2025 and 2030 (Gg CO_2 eq)

Energy Sector	2020			2025			2030		
	WOM	WEM	WAM	WOM	WEM	WAM	WOM	WEM	WAM
Electricity Generation (electricity and heat production)	116,622.57	101,205.68	100,622.32	140,032.90	105,132.60	101,757.81	168,869.81	98,657.16	91,442.19
Oil Refining	6,175.89	6,114.13	6,052.37	6,175.89	6,114.13	6,052.37	6,175.89	6,114.13	5,434.78
Natural Gas Transformation	20,608.80	20,402.71	20,196.62	20,608.80	20,402.71	20,196.62	20,608.80	20,402.71	18,135.74
Manufacturing Industries and Construction	35,433.20	35,416.17	35,390.61	42,952.68	42,931.90	42,902.42	55,607.42	55,580.30	55,544.08
Transport	64,115.35	63,381.67	62,103.52	70,220.93	70,220.93	68,158.99	66,333.98	66,333.98	64,473.44
Commercial/ Institution	2,795.29	2,793.93	2,792.50	3,116.85	3,115.32	3,113.73	3,434.82	3,433.13	3,431.38
Residential	1,751.09	1,751.09	1,751.09	1,675.64	1,675.64	1,675.64	1,535.41	1,535.41	1,535.41
Agriculture, Forestry and Fishing/Fish Farm	2,954.26	2,954.26	2,954.26	3,142.77	3,142.77	3,142.77	3,503.85	3,503.85	3,503.85
Fugitive Emissions	22,959.56	21,890.25	21,189.00	22,689.84	17,985.86	13,281.88	22,480.24	13,747.27	5,014.29
Total Energy	**273,416**	**255,910**	**253,052**	**310,616**	**270,722**	**260,282**	**348,550**	**269,308**	**248,515**

3.3.3.2 Industrial Processes and Product Use Sector

From the GHG Inventory, within this sector in 2019, the metal industry contributed the highest share (39.8%) of the sector's GHG emissions, followed by mineral industry (30.7%), the chemical industry (17.5%) and the electronics industry (8.5%). GHG emissions from industrial processes however were projected to increase in these sub-sectors over the next decade due to expansion of production capacity, especially in the iron and steel industry. Emissions from the iron and steel industry would depend on control on the number and capacity of iron and steel mills approved for production. Except for the cement and iron and steel industries, differences in the GHG emissions between WOM, WEM and WAM scenarios for the other sub-sectors in this assessment were basically based on production growth rates.

Production of cement in Malaysia increased from 16.66 million tonnes in 2005 to 20.04 million tonnes in 2019. The cement production is projected to grow at about 2.5% per year until 2030, based on the existing capacity of 48.959 million tonnes per annum and with an operating capacity of 41%. Cement production in Malaysia is highly concentrated, with the top five players having a total market share of 90%.

Reduction of emissions from energy usage has been taken into account in the energy sector calculations, hence this section shall only concentrate on the option of decreasing the share of clinker in cement production by adding additives like fly ash. In the first Biennial Update Report (BUR1), it has been recommended that the cement industry in Malaysia could reduce its clinker ratio to 0.75:1 by the year 2030 to help reduce emissions from cement production. Based on this, the proposed clinker content per tonne of cement in the WOM, WEM and WAM scenarios are as shown in Table 3.8.

Table 3.8: Summary of Proposed Mitigation Scenarios for Cement Production

Mitigation Action	WOM Scenario	WEM Scenario	WAM Scenario
Reduce clinker ratio in cement production	The clinker ratio to cement is at 88% (0.82:1) level until 2030.	Cement producers to reduce the clinker ratio from 88% in 2019 to 81% in 2030.	Clinker ratio to be reduced from 88% in 2019 to 78% in 2030.

Based on the aforementioned assumptions, the projected GHG emission growths in all the three scenarios for the IPPU sector is as shown in Figure 3.5 and Table 3.9. Here the GHG emissions for each of the sub-sector is estimated for the projection period based on each sub-sector's projected production and using the 2006 IPCC Guidelines. The GHG emission is projected to grow from 32,853 Gg CO_2 eq in 2019 to 82,462 Gg CO_2 eq, 56,585 Gg CO_2 eq and 50,662 Gg CO_2 eq for the WOM, WEM and WAM scenarios respectively in 2030.

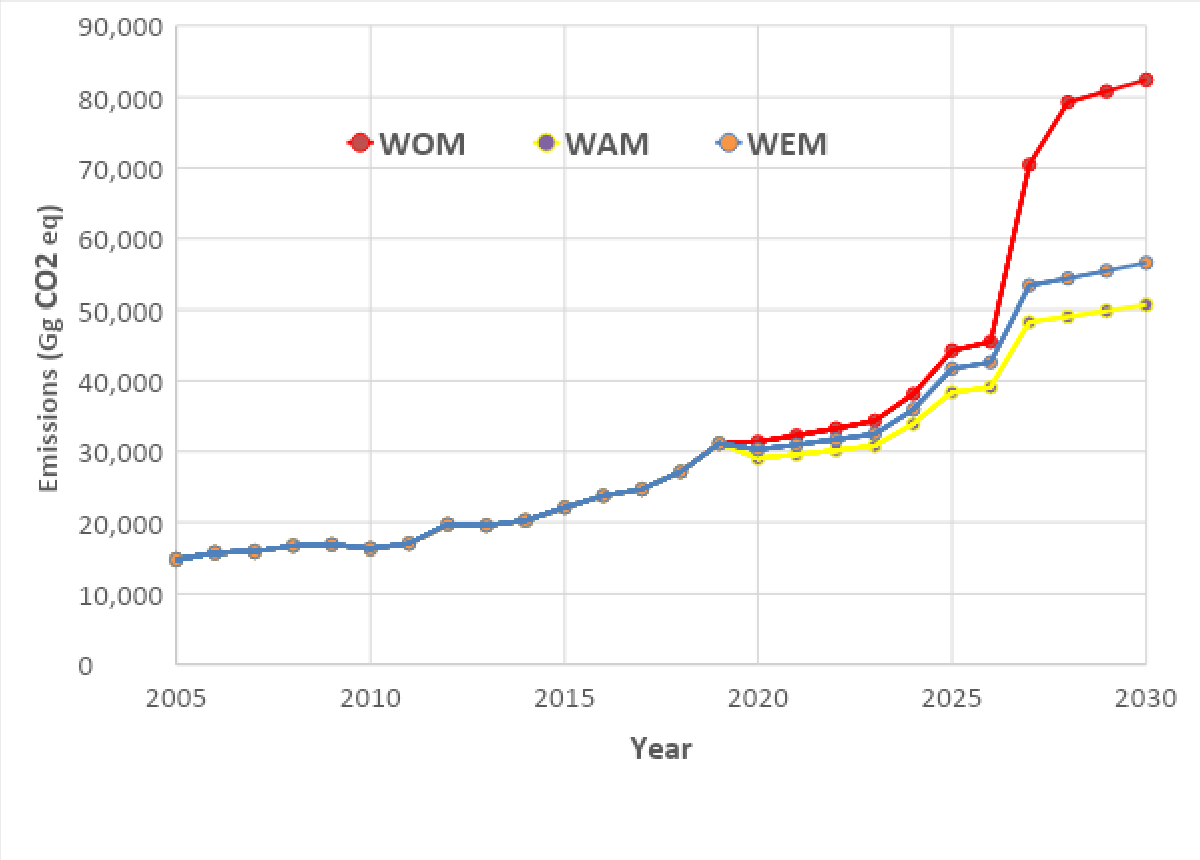


Figure 3.5: Projected GHG Emissions for the IPPU Sector for WOM, WEM and WAM Scenarios

Table 3.9: Projected GHG Emission for the IPPU Sub-Sectors under WOM, WEM and WAM Mitigation Scenarios in 2020, 2025 and 2030 (Gg CO_2 eq.)

Sub-sector	2020			2025			2030		
	WOM	WEM	WAM	WOM	WEM	WAM	WOM	WEM	WAM
Mineral Industry	10,194.51	9,466.97	9,083.08	10,762.30	9,990.70	9,583.57	11,365.54	10,547.22	10,115.43
Chemical Industry	6,353.80	6,195.06	6,142.21	8,782.40	7,647.62	7,209.06	12,067.09	9,559.60	8,445.75
Metal Industry	10,704.58	10,551.28	9,732.67	18,700.41	18,459.51	16,335.89	50,191.53	28,763.27	25,337.59
Electronics Industry	3,041.61	2,999.75	2,957.89	4,679.89	4,306.53	3,958.33	7,200.59	6,182.58	5,297.14
Product Uses as Substitute for ODS	876.27	876.27	876.27	1,092.05	1,042.74	1,010.82	1,306.35	1,201.03	1,135.06
Other Product Manufacture & Use	214.56	214.56	214.56	267.45	267.45	267.45	331.27	331.27	331.27
Total Emissions	**31,385**	**30,304**	**29,007**	**44,285**	**41,715**	**38,365**	**82,462**	**56,585**	**50,662**

Note: *ODS refers to Ozone Depleting Substances.*

3.3.3.3 Agriculture

As mentioned earlier food security is one of the key concerns of Malaysia. In 2019 emissions from the agriculture sector was about 9,922 Gg CO_2 eq., with direct N_2O emissions from managed soils accounting for about 3,737 Gg CO2 eq. (37.7%) of the emissions and rice cultivations accounting for about 2,269 Gg CO2 eq. (22.9%) of the emissions. Increasing self-sufficiency in food production especially livestock would lead to increase level of GHG emissions.

Reducing emissions from the agriculture sector through good agriculture practices would include optimising the usage of synthetic fertiliser for crop yield. This can be achieved by applying what is commonly known as the 4R's:

- Right N application rate
- Right formulation (fertiliser type)
- Right timing of application, and
- Right placement

Discussions with the agriculture research institutions indicate the possibility of reduction of about 10% of synthetic fertiliser application through the 4R strategy for oil palm cultivation, the largest crop under cultivation in Malaysia. The assumption for reducing synthetic fertiliser application for the WOM, WEM and WAM scenarios for the agriculture sector is as shown in Table 3.10.

Table 3.10: Summary of Proposed Mitigation Scenarios for Oil Palm Cultivation

Mitigation Action	WOM Scenario	WEM Scenario	WAM Scenario
Improved nitrogenous fertiliser management for oil palm cultivation	The application rate of fertilizer usage: 90 kg N per year per hectare for young oil palm and 105 kg N per year per hectare for mature oil palm.	The application rate of fertiliser usage: 90 kg N per year per hectare for young oil palm and 105 kg N per year per hectare for mature oil palm.	Assume that the application rate of nitrogenous fertilisers reduces by 10% from 2020 onwards through optimum application of synthetic fertiliser.

Efforts are also being taken to limit the areas under oil palm cultivation. While the WOM scenario would likely see oil palm cultivation reaching 7 million hectares, efforts are being taken by the Ministry of Plantation and Commodities to restrict oil palm cultivation to a maximum land usage of 6.5 million hectares by 2030 which was used for the WEM and WAM modelling scenarios.

For rice cultivations, increasing productivity per hectare of paddy planted area especially in the irrigated granaries, would reduce the need of additional land for rice cultivation. The National Agrofood Policy 2.0 2021-2030 (NAP 2.0) and Action Plan targeted a productivity of 7 tonnes of paddy yield per hectare especially in the granaries by 2030. This scenario was used for the WAM case, while the WEM used a mid-value productivity yield value of 5.7 tonnes of paddy per planted by 2030 and the WOM scenario used the 2005-2019 average productivity yield of 4.576 tonnes per hectare of granary planted area.

Livestock population emissions were modelled based on the full achievement of NAP 2.0 meat and dairy self-sufficiency ratio (SSR) targets for the WOM case and the 66% achievement of NAP 2.0 SSR targets for the WEM case based on historical trends and from reverse investment initiatives. While the achievement of the 33% SSR objective for the WAM is because of food imports contributing to a decrease in GHG emissions.

Based on the aforementioned assumptions, the projected GHG emissions for the three scenarios for the agriculture sector is as shown in Figure 3.6 and Table 3.11. The projections indicated that the GHG emissions for the agriculture sector would grow from 9.922 Gg CO_2 eq. in 2019 to 16,256 Gg CO_2 eq., 13,615 Gg CO_2 eq. and 11,309 Gg CO_2 eq. under the WOM, WEM and WAM scenarios in 2030.

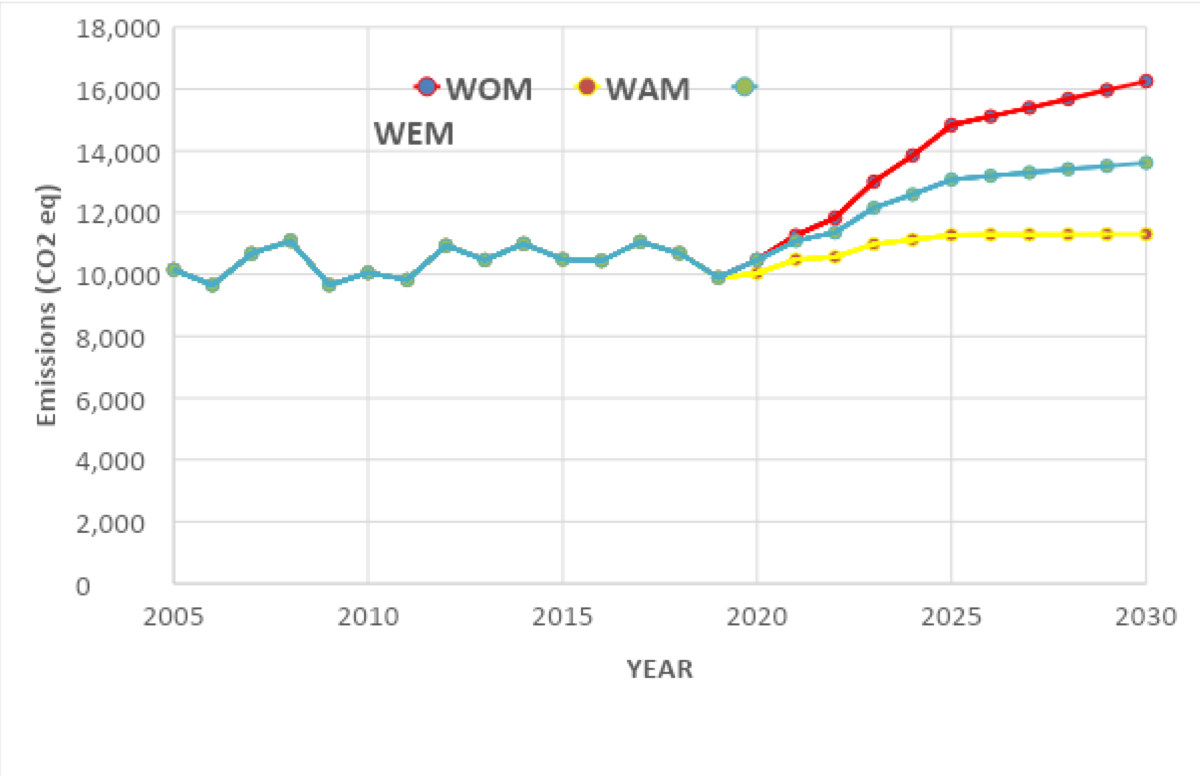


Figure 3.6: Projected GHG Emissions for the Agriculture Sector for WOM, WEM and WAM Scenarios

Table 3.11: Projected GHG Emission for the Agriculture Sub-Sectors under WOM, WEM and WAM Mitigation Scenarios in 2020, 2025 and 2030 (Gg CO_2 eq.)

Sub-sector	2020			2025			2030		
	WOM	WEM	WAM	WOM	WEM	WAM	WOM	WEM	WAM
Enteric Fermentation	1,228.45	1,228.45	1,228.45	3,122.92	2,475.58	1,704.72	3,299.63	2,562.40	1,656.57
Manure Management	659.63	659.63	659.63	896.60	824.40	738.85	1,002.09	890.80	772.54
Biomass burning in Croplands	10.01	10.01	10.01	14.37	11.48	10.36	16.58	11.73	9.56
Liming	21.01	21.01	21.01	27.60	23.30	21.63	30.89	23.68	20.44
Urea Application	519.50	519.50	461.70	590.97	565.54	510.01	632.12	579.82	523.22
Direct N_2O Emissions from managed soils	4,092.73	4,092.73	3,808.79	4,851.20	4,595.61	4,170.89	5,227.91	4,779.13	4,297.66
Indirect N_2O Emissions from managed soils	1,164.11	1,164.11	1,071.83	1,424.45	1,331.50	1,192.10	1,556.84	1,391.55	1,228.85
Indirect N_2O Emissions from manure management	556.31	556.31	556.31	785.89	708.73	627.78	931.15	790.43	653.52
Rice cultivations	2,247.72	2,247.72	2,247.72	3,115.07	2,533.65	2,308.40	3,559.60	2,585.68	2,147.51
Total Emissions	**10,499**	**10,499**	**10,065**	**14,829**	**13,070**	**11,285**	**16,257**	**13,615**	**11,310**

3.3.3.4 Waste

GHG emissions from the waste sector arise from two major sources, i.e., solid waste disposal and wastewater treatment and discharge (domestic and industrial), where most of the emissions are in the form of methane. Out of the 28,257 Gg CO_2 eq. of GHG emissions from this sector in 2019, industrial waste water treatment and discharge contributed 51% (14,462 Gg CO_2 eq.) of the emissions with nearly 99% of this part of the emission coming from POME. Solid waste disposal sites contributed 41% (11,681 Gg CO_2 eq.) of the emissions and domestic waste water contributed 7% (2,065 Gg CO_2 eq.) of the emissions.

Logically the mitigation efforts in this sector should be focused on reducing methane emissions from solid waste disposal sites and from POME. Table 3.12 is a summary of the mitigation actions assumed for the WOM, WEM and WAM scenarios in the projection. The assumptions for recycling follow closely the targets set in the policies.

For methane recovery from POME, although the earlier policies proposed the implementation of biogas capture facilities for 500 palm oil mills by 2020, the uptake by that industry has been slower than expected where in 2019 only 125 out of 452 palm oil mills have been fully equipped with biogas capture facilities. Based on discussions with the Ministry of Plantation and Commodities and the Malaysian Palm Oil Board (MPOB) it is projected that the yearly increment of mills with biogas capture would be five per year. It is evident that greater push for implementation of biogas capture facilities in palm oil mills is needed.

Table 3.12: Summary of Mitigation Actions by Scenarios for the Waste Sector

Mitigation Actions	WOM Scenario	WEM Scenario	WAM Scenario
Increase solid waste recycling rate: (i) Encouraging waste separation at source; (ii) Reduction of organic waste generation; (iii) Paper recycling activities; (iv) Encouraging 3R and using waste as a resource for other industries.	The recycling rate remains at 2019 value (31 %) from 2020 to 2030.	The recycling rate increases from 31% in 2019 to 35.5% by 2025 and remains at that value till 2030.	The recycling rate increases from 31% in 2019 to 40% by 2025 and remains at that value till 2030.

Mitigation Actions	WOM Scenario	WEM Scenario	WAM Scenario
Increase proper treatment of industrial wastewater: (i) Increase capture of methane from POME by installing biogas capture facilities in existing palm oil mills and mandatory for new palm oil mills to install biogas capture facilities.	Assume the number of biogas capture facilities at POME treatment sites remain the same as per 2019 values. Methane captured in POME biogas treatment facilities is 50% for flaring and 50% for energy use. The flaring efficiency of methane is at 50%.	The number of biogas capture facilities at POME treatment sites increase by five per year. Methane captured in POME biogas treatment facilities is 50% for flaring and 50% for energy use in 2020 and increases to 25% for flaring and 75% for energy use from 2021 onwards. The flaring efficiency of methane increased from 50% in 2019 to 80% in 2020 onwards. .	The number of biogas capture facilities at POME treatment sites increase by five per year. Methane captured in POME biogas treatment facilities is 50% for flaring and 50% for energy use in 2020 and increases to 25% for flaring and 75% for energy use from 2021 onwards. The flaring efficiency of methane increased from 50% in 2019 to 80% in 2020 and 100% by 2025.

Figure 3.7 and Table 3.13 show the projected GHG emissions from 2020 to 2030 for the WOM, WEM and WAM mitigation scenarios. The results indicate that GHG emissions from the waste sector would grow from 28,257 Gg CO_2 eq in 2019 to 34,094 Gg CO_2 eq. and 28,095 CO_2 eq. under the WOM and WEM scenarios respectively in 2030. However, under the WAM scenario the GHG emissions from the waste sector could reduce to 27,067 Gg CO_2 eq. in 2030. This could be achieved by diverting organic wastes away from landfills for treatment and greater implementation ambition on establishing biogas capture facilities at palm oil mills as well as better flaring efficiency and usage of the methane captured in these facilities for energy generation.

Figure 3.7: Projected GHG Emission for the Waste Sector for WOM, WEM and WAM Scenarios

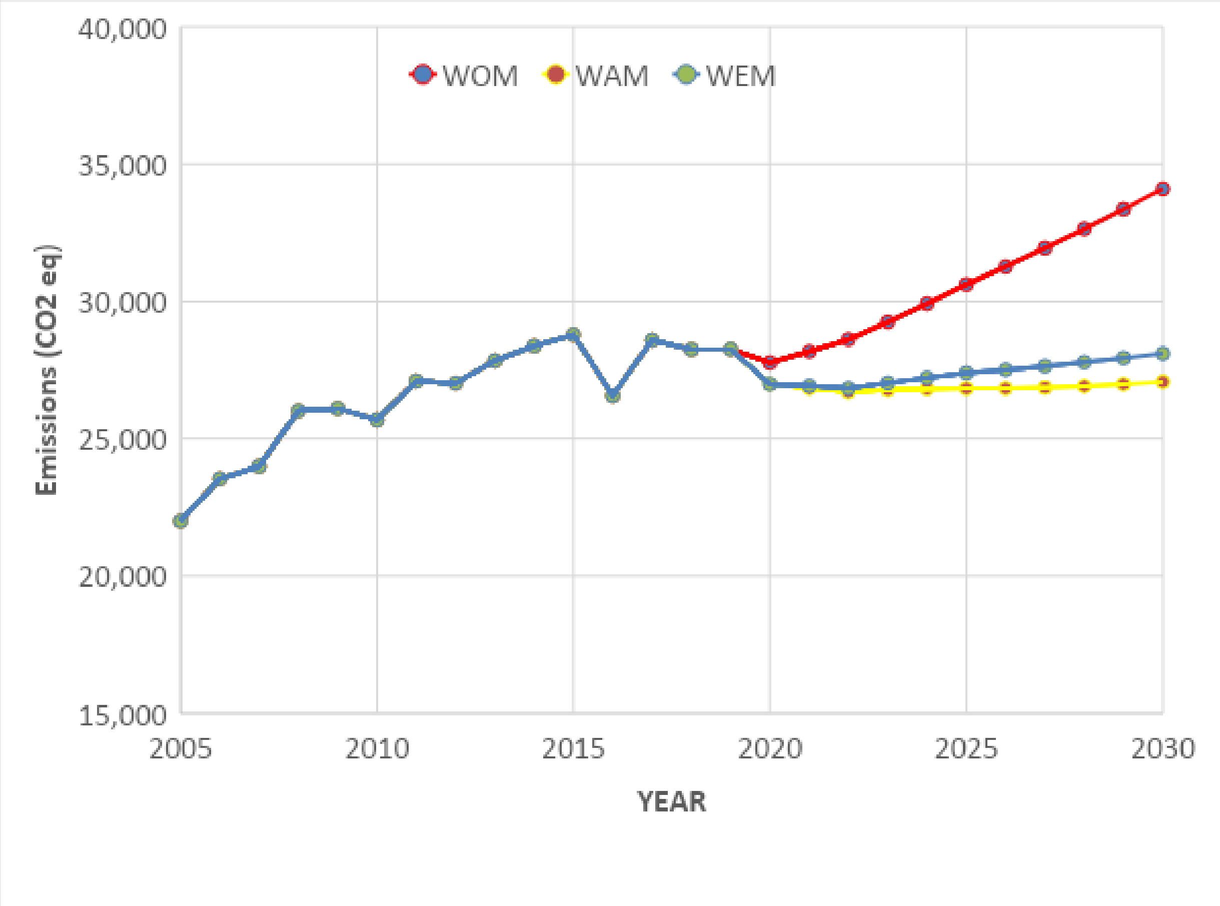


Table 3.13: Projected GHG Emission for the Waste Sub-Sectors under WOM, WEM and WAM Mitigation Scenarios in 2020, 2025 and 2030 (Gg CO_2 eq.)

Sub-Sector	2020			2025			2030		
	WOM	WEM	WAM	WOM	WEM	WAM	WOM	WEM	WAM
Solid Waste Disposal Sites	11,650.13	11,650.13	11,650.13	11,586.14	11,370.00	11,156.39	12,158.16	11,589.91	11,019.32
Biological Treatment of Solid Waste	0.44	0.44	0.44	0.62	0.62	0.62	0.86	0.86	0.86
Incineration	45.90	45.90	45.90	54.60	54.60	54.60	67.13	67.13	67.13
Open Burning	2.72	2.72	2.72	2.72	2.72	2.72	2.56	2.56	2.56
Domestic Wastewater	2,060.42	2,031.61	2,031.61	2,287.45	2,091.50	2,091.50	2,416.96	2,029.65	2,029.65
Industrial Wastewater	14,007.90	13,256.39	13,256.39	16,680.39	13,872.51	13,523.35	19,448.13	14,404.51	13,947.88
Total Emissions	**27,768**	**26,987**	**26,987**	**30,612**	**27,392**	**26,829**	**34,094**	**28,095**	**27,067**

3.3.3.5 Land Use, Land-Use Change and Forestry

Of the five categories of land use under the IPCC categories, forest and crop land are the most important categories. These two categories account for more than 75% of the total land use of Malaysia. Some of the wetlands like peatland is reported in both forest and cropland. Mitigation potential for grassland and wetlands are relatively small while assessment for settlements is being undertaken.

Net Forest Change

Malaysia's deforestation rates stabilised, between 2009 to 2015 there was no net forest loss. However, the increasing population (estimated to reach 38 million by 2030) together with increased demand for food, transportation and other infrastructures puts pressure on forest.

Projected forest loss between 2020 and 2030 was derived from historic rate of forest conversion. Figure 3.8 shows the projected forest cover until 2030. Forest loss of 65,000 ha per year is expected under the WOM scenario between 2020 and 2030 while in the WEM and WAM scenarios, 50,000 ha and 47,000 ha respectively were projected to be lost annually over the same period.

Based on these scenarios, Malaysia would still maintain 52.7%, 53.1% and 53.2% of its total land area as forest under the WOM, WEM and WAM scenarios respectively in 2030 (Table 3.14).

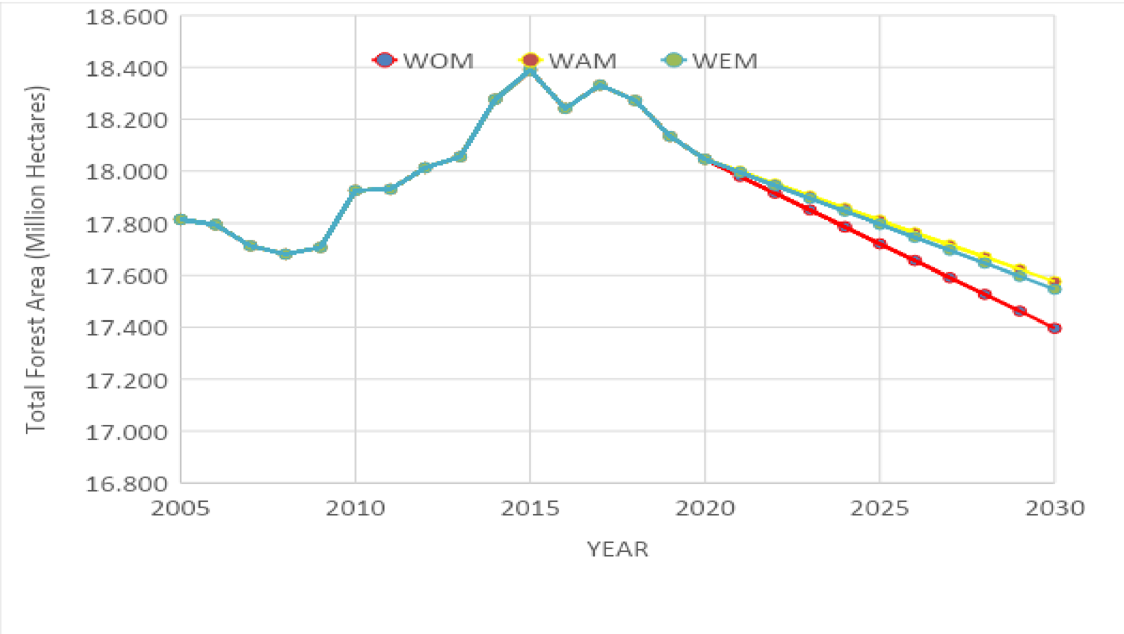


Figure 3.8: Projected Forest Cover in Malaysia for WOM, WEM and WAM Scenarios from 2020 to 2030

Table 3.14: Projected Forest Cover for WOM, WEM and WAM Scenarios in 2020, 2025 and 2030

Year	Total Forest Cover (million hectare)		
	WOM	WEM	WAM
2020	18.046	18.046	18.046
2025	17.721	17.796	17.811
2030	17.396	17.546	17.576

Sustainable Forest Management

With the implementation of sustainable forest management and forest certification, the maximum harvest is limited to 85m^3/ha and follows all the principles, criteria and indicators set in Malaysia Criteria and Indicator (MC&I). The historical rate of decrease in wood harvest is about 4% per annum from 2005 to 2019. The current scenarios do not include potential enhancement of carbon stocks in degraded forest especially when forest corridors are established. It only considered the increment in carbon stocks, drained organic soils and commercial harvest.

For the mitigation assessment, a conservative assumption was made for the projected commercial wood harvest. For all the three scenarios wood harvest are projected to increase from 2020 to 2025 and then reduce from then onwards to 2030 (Table 3.15). By 2030, with the decreasing harvest rate from 2025 onwards, the projected commercial harvest is around 16.051 million m^3 per year, 14.891 million m^3 per year and 13.726 million m^3 per year for WOM, WEM and WAM scenarios respectively.

Table 3.15: Projected Commercial Wood Harvest for WOM, WEM and WAM Scenarios in 2020, 2025 and 2030

Year	Total Commercial Harvest (m^3)		
	WOM	WEM	WAM
2020	15,284,535	14,839,355	14,394,175
2025	17,086,675	16,208,191	15,324,845
2030	16,050,767	14,890,776	13,726,318

Cropland

The expansion of cropland area is limited in Malaysia due to limited arable land targeted for agriculture. Labour shortage has also resulted in abandoned farms especially for rubber and rice cultivation. The current trend in oil palm expansion comes primarily from abandoned cropland and this trend may continue. The projected growth in the cropland is focused on enhancing productivity of the smallholders engaged in commodity tree crops like oil palm and rubber. The expansion of tree crops under the WOM, WEM and WAM scenarios are shown in Table 3.16.

Table 3.16: Projected Areas under Cropland for WOM, WEM and WAM Scenarios in 2020, 2025 and 2030 (hectares)

Year	Cropland Area (ha)											
	WOM				WEM				WAM			
	Oil Palm*	Rubber	Cocoa	Total	Oil Palm*	Rubber	Cocoa	Total	Oil Palm*	Rubber	Cocoa	Total
2020	5,910,000	1,132,000	6,100	7,048,100	5,865,000	1,132,000	6,100	7,003,100	5,865,000	1,132,000	6,100	7,003,100
2025	6,431,951	1,132,000	6,100	7,570,051	6,174,342	1,132,000	6,100	7,312,442	6,174,342	1,132,000	6,100	7,312,442
2030	7,000,000	1,132,000	6,100	8,138,100	6,500,000	1,132,000	6,100	7,638,100	6,500,000	1,132,000	6,100	7,638,100

Source: MPC, 2023.

Projected LULUCF Emissions and Removals

For the forest category, enhancing sustainable forest management (SFM) and conservation would reduce emission. The implementation of CFS and HoB have potential to increase forest connectivity and enhance removals. It is anticipated that future supply of wood from the plantation forest would increase and lesser harvesting would occur from natural forest. Deforestation would occur in the State Land Forest. Biomass loss of 140t d.m./ha, 127t d.m./ha and 144t d.m./ha for forest, oil palm and rubber respectively were applied in the calculation of GHG emissions. For deforestation, it is assumed that all of the above ground biomass is removed.

For Cropland, marginal increase in removals is anticipated while conversion of cropland to settlement would also be stabilised. It is anticipated that 7,600 ha of rubber plantation and 2,000 ha of oil palm will be converted to settlement on annual basis respectively.

The total emission and removals from forest and crop land is shown in Table 3.17 under the three scenarios.

Figure 3.9: Projected GHG Emission for the LULUCF Sector for WOM, WEM and WAM Scenarios

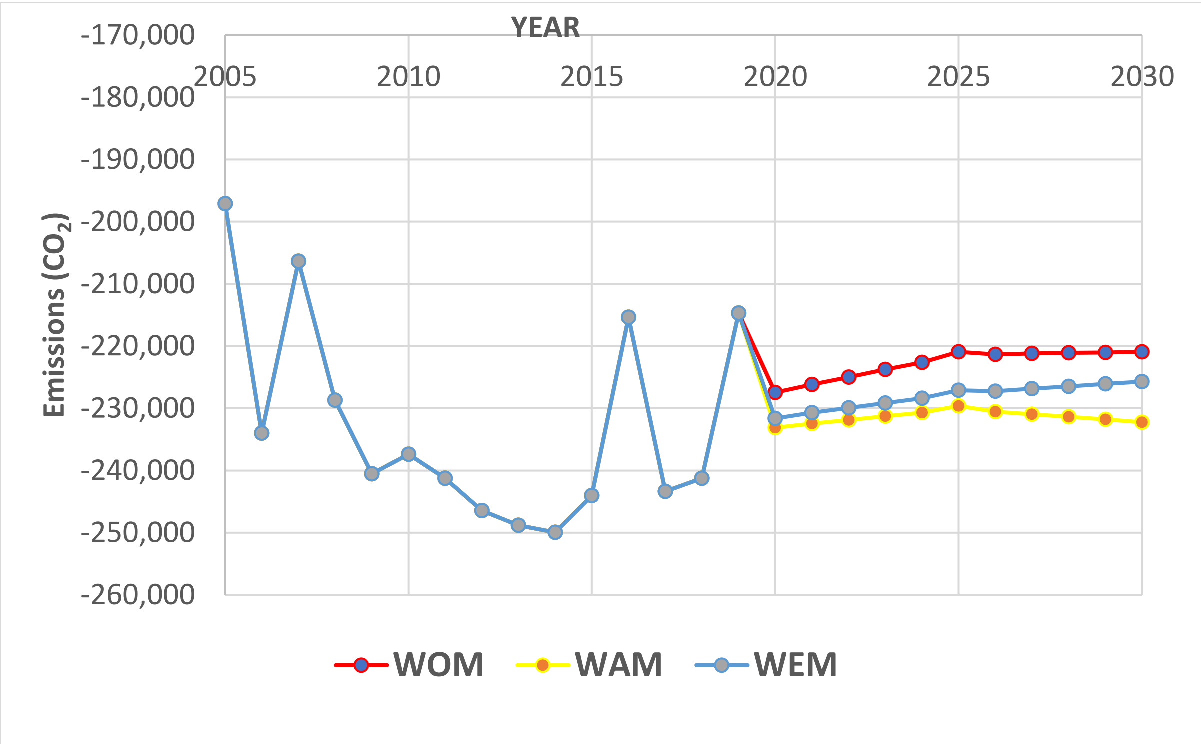


Table 3.17: Projected GHG Emissions for the LULUCF Sector under WOM, WEM and WAM Scenarios in 2020, 2025 and 2030 (Gg CO_2eq)

Sub-sector	2020			2025			2030		
	WOM	WEM	WAM	WOM	WEM	WAM	WOM	WEM	WAM
Forest Land Remaining Forest Land	-228,980.31	-229,785.86	-230,591.42	-219,084.27	-223,307.01	-225,096.66	-215,437.64	-219,816.11	-225,608.52
Cropland Remaining Cropland	-16,536.35	-16,247.60	-16,247.60	-19,885.54	-18,232.54	-18,232,54	-23,530.51	-20,322.18	-20,322.18
Forest Land converted to Cropland	3,619.00	0.00	0.00	3,619.00	0.00	0.00	3,619.00	0.00	0.00
Land converted to Settlement	14,418.10	14,418.10	13,694.30	14,418.10	14,418.10	13,694.30	14,418.10	14,418.10	13,694.30
Total Emissions	**-227,480**	**-231,615**	**-233,145**	**-220,933**	**-227,121**	**-229,635**	**-220,931**	**-225,720**	**-232,236**

3.4 Plan for Improvement

As mitigation actions through different policies and programmes are being implemented across the different Ministries and Agencies, a coherent and robust Measurement, Reporting and Verification (MRV) System is necessary for keeping track of the integrated impacts of these implementations in reducing the GHG emissions in the country. A step-wise approach has been taken in developing this system in Malaysia with the Ministry of Natural Resources and Environmental Sustainability as the Secretariat to the Technical Working Group of Mitigation and Technical Working Group on Transparency and Related Activities.

In moving strategic directions in implementing the policies that will give effect to GHG emission reduction, one of the critical information that is sought by policymakers is accurate information on projection of future GHG emissions. The current efforts in modelling the projected emissions are the efforts in providing such information for informed decisions making on strategic directions for implementing mitigation actions. More accurate modelling is required, in particular those coupled with accurate information on abatement costs. Moving towards more sophisticated models would be attempted.

CHAPTER 4

4. VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

4.1 Introduction

Vulnerability assessment and adaptation measures are an important component of the national response to address climate change as highlighted in Malaysia's First Update of Nationally Determined Contribution 2021 (NDC 2021) to the UNFCCC. As described in chapter one of this report, the country has experienced increased minimum, mean and maximum air temperatures. The rainfall intensity has also increased. Over the last two decades more weather extremes had been experienced by the country. Major floods occurred in 2010, 2012 and 2014, 2021 and 2022 with the 2014 northeast monsoon floods being one of the worst in recorded history. In 2016, a very strong *El Niño* resulted in prolonged dry periods and associated water shortages, heat waves and wildfires. Consequently, economic losses have also increased.

Building resilience to natural climate variability and anthropogenic climate change requires systematic vulnerability and adaptation assessment. The vulnerability and adaptation assessment reported in this chapter captures the progress made in climate change projection as well as sectoral vulnerability and impact assessment since NC3.

This chapter on vulnerability assessment and adaptation measures is concurrently submitted as Malaysia's First Adaptation Communication pursuant to the Paris Agreement, which was prepared taking into account Decision 9/CMA.1.

4.2 Institutional Arrangement

The institutional arrangement for V&A assessment is shown in Figure 1.10 and the implementation arrangement is shown in this report. The Technical Working Group on Vulnerability and Adaptation (TWG V&A) is chaired by the National Water Research Institute of Malaysia (NAHRIM) under the Ministry of Natural Resources and Environmental Sustainability (NRES) Malaysia and supported by six Sub-Working Groups (SWGs). The six SWGs are led by the following ministries and agencies as listed below:

i. Water and Coastal Resources - Department of Irrigation and Drainage (DID), NRES;
ii. Agriculture and Food Security - Malaysian Agriculture Research and Development Institute (MARDI), Ministry of Agriculture and Food Security (MAFS);
iii. Forest and Biodiversity - Forestry Department of Peninsular Malaysia, NRES;
iv. Cities, Built Environment and Infrastructure - Department of Town and Country Planning (PLANMalaysia), Ministry of Local Government Development;
v. Energy - Energy Division, Ministry of Economy; and

vi. Public Health - Institute for Medical Research (IMR), and Disease Control Division, Ministry of Health (MOH)

4.3 Improvement since NC3

A number of improvements for climate and sea level rise (SLR) projections had been carried out in this assessment as summarised in Table 4.1. The major improvements include flood areal extent analysis for Sabah and Sarawak, dry spell analysis for the whole of Malaysia, coastal inundation analysis, and projected extreme events associated with return periods for sectoral vulnerability and impact assessment purposes.

Table 4.1: Summary of Climate and SLR Projections and Their Assessments for NC3 and NC4

Item	NC3		NC4	
	PENINSULAR MALAYSIA	SABAH & SARAWAK	PENINSULAR MALAYSIA	SABAH & SARAWAK
(A) HYDROCLIMATE PROJECTION				
IPCC Assessment Report	**AR4**		**AR5**	
Number of GCMs	**3**	**2**	**5**	
Name of GCMs	**ECHAM5 MRI-CGCM2.3.2 CCSM3**	**ECHAM5 MRI-CGCM2.3.2**	**CCSM4 MIROC5 MRI-CGCM3 GFDL-ESM2M IPSL-CM5A-LR**	
Scenario	**A1FI, A2, A1B, B1**	**A1B**	**RCP 2.6, 4.5, 6.0 & 8.5**	
Realisations	**15**	**4**	**16**	
Regional Downscaling Model	**RegHCM-PM**	**RegHCM-SS**	**RegHCM-PM 2.0**	**RegHCM-SS 2.0**
Spatial Resolution	**6 km**	**9 km**	**6 km**	
Meteorological Parameters	**Rainfall, Air Temperature**		**Rainfall, Air Temperature**	
Time Resolution	**Hourly**		**Hourly**	
Projected Period	**2010-2100**		**2010-2100**	
ASSESSMENTS				
Flood				
Area	**15 basins**	**Not carried out**	**17 basins**	**20 basins**
Period	**2030 & 2050**	**Not carried out**	**2100 (early to late-century)**	**2010-2054 (early to mid-century); 2055-2100 (mid to late-century)**
Dry Spell				

Item	NC3		NC4	
	PENINSULAR MALAYSIA	SABAH & SARAWAK	PENINSULAR MALAYSIA	SABAH & SARAWAK
Area	**Whole country**		**Whole country**	
Period	**Yearly: 2010-2100**		**Monthly and yearly:** • **2020-2046 (early-century)** • **2047-2073 (mid-century)** • **2074-2100 (late-century)**	
Extreme Events (Dry and Wet)				
Area	**Not carried out**		**Whole country**	
Period	**Not carried out**		**Monthly and yearly:** • **2020-2046 (early-century)** • **2047-2073 (mid-century)** • **2074-2100 (late-century)**	
(B) SEA LEVEL RISE				
IPCC Assessment Report	**AR4**		**AR5**	
Number of AOGCMs	**7**		**29**	
Name of GCMs	**CGCM3.1, GISS-AOM, GISS-ER, MIROC3.2(hires), MIROC3.2(medres), ECHO-G, MRI-CGCM2.3.2a**		**CMIP5: ACCESS1-0, ACCESS1-3, CanESM2, CCSM4, CESM1-BGC, CESM1-CAM5, CMCC-CESM, CMCC-CMS, CNRM-CM5, CSIRO-MK3-6-0, FGOALS-g2, FIO-ESM, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, GISS-E2-R, HadGEM2-CC, HadGEM2-ES, INMCM4, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, MIROC-ESM-CHEM, MIROC-ESM, MPI-ESM-LR, MRI-CGCM3, NorESM1-ME, NorESM1-M**	
Scenario	**A2, A1B, B1**		**RCP 2.6, 4.5, 6.0 & 8.5**	
Realisations	**49**		**93**	
Time Resolution	**Yearly**		**Monthly**	
Projected Period	**2000-2100**		**2015-2100**	
ASSESSMENTS				
SLR				
Area	**Whole country**		**Whole country**	
Period	**2030 & 2050**		**2050 & 2100**	
Coastal Inundation				
Area	**Not carried out**		**Whole country**	
Period	**Not carried out**		**2050 & 2100**	

For the V&A assessments, the same sectors as reported in NC3 with some additional sub-sectors were assessed in this report (Table 4.2). The assessment on impacts of floods, dry spells, extreme high temperatures and extreme wet events, were carried out based on the hydroclimate data projected under the RCP 6.0, while the assessment on impacts of SLR and coastal inundation were carried out based on the sea level data projected under the RCP 8.5.

The RCP 6.0 scenario was chosen since this RCP is almost similar to the SRES A1B that was used in NC3 as well as being close to the current anthropogenic global warming rate. For SLR, the RCP 8.5 was chosen in order to take into account the impacts of other coastal hazard such as storm surges and wind generated wave which are not included in the static SLR vulnerability assessment that was adopted in this report.

Table 4.2: Summary of Sectoral Impact and Vulnerability Assessments for NC3 and NC4

NC3					NC4				
Sector & Sub-Sector Assessments	Flood	Dry Spell / Temp.	SLR	Sea Temp.	Sector & Sub-Sector Assessments	Flood	Extreme event: Dry Spell / Temp.	Extreme event: Wet	SLR / Coastal Inun.
Water and Coastal Resources									
Reservoir Storage and Dam Security	√	√			Reservoir Storage and Dam Security		√	√	
Flood Risk Management	√				Flood Risk Management	√			√
Groundwater Security			√		Groundwater Security				√
Coastal Erosions and Vulnerability			√		Coastal Erosions				√
Agriculture and Food Security									
Rice	√	√	√		Rice	√	√		√
Oil Palm	√				Oil Palm	√	√		√
Rubber	√	√			Rubber	√	√	√	√
Cocoa	√	√			Cocoa	√	√		
Livestock	√	√			Livestock	√	√		
Fisheries				√	Fisheries & Aquaculture	√	√		√
Aquaculture				√					
Forestry and Biodiversity									
Inland Forest		√			Inland Forest		√		√
Peat Swamp Forests		√			Peat Swamp Forest		√		√
Mangrove			√		Mangrove Forest		√		√
Terrestrial Fauna (birds, orang utans, elephant)		√			Terrestrial Fauna (birds, orang utan, elephant, tiger, sambar deer)	√	√		

NC3					NC4				
Sector & Sub-Sector Assessments	Flood	Dry Spell / Temp.	SLR	Sea Temp.	Sector & Sub-Sector Assessments	Flood	Extreme event		SLR / Coastal Inun.
							Dry Spell / Temp.	Wet	
Marine Ecosystem (coral reefs, marine turtle)				√	Marine Ecosystem (coral reefs, marine turtle, marine mammals)				√
Infrastructure (NC3) / Cities, Built Environment & Infrastructure (NC4)									
Buildings and Flood Relief Centres	√				Cities	√	√		√
Roads and Drainage	√	√	√		Built Environment	√	√		√
Transportation: - Railway	√	√			Road	√			√
- Airport	√	√			Rails	√			√
- Port & jetty			√		Ports & Jetties	√	√		√
Water Supply Facilities	√	√	√		Airports	√	√		√
Sewerage Facilities	√	√	√		Solid Waste Facilities	√	√		√
Solid Waste Facilities	√	√	√		Sewerage Facilities	√			√
					Water Supply Facilities	√	√		
					Flood Relief Centres	√			√
Energy									
Electricity Generation, Transmission and Distribution	√	√	√		Electricity Generation, Transmission and Distribution	√	√	√	√
Oil and Gas	√	√	√		Oil and Gas	√	√		√
Public Health									
Healthcare Facilities	√		√		Healthcare Facilities	√			√
Dengue	√	√			Vector Borne Diseases (Dengue & Malaria)	√	√		
Malaria		√	√		Food and Water Borne Diseases	√			
Food and Water Borne Diseases	√	√			Leptospirosis	√			
					Heat Related Illness		√		

4.4 Projected Hydroclimate

4.4.1 Air Temperature

Projected average annual air temperatures for the periods of early-century, mid-century and late-century for the hydrological regions of the country, is shown in Figure 4.1. The average annual air temperatures for the whole country showed an increasing trend and could increase by 0.5-0.8 ^{o}C in early-century, 1.1-1.5 ^{o}C by mid-century, and 1.7-2.1 ^{o}C by late-century. Among the regions, Region SW-1 in Sarawak was estimated with the highest increment throughout the century.

4.4.2 Rainfall

As shown in Figure 4.2, all the hydrological regions in the country are expected to face increments of average annual rainfall throughout the century. Overall, the regions in Sabah and Sarawak showed higher increments during the early-century (6.7-15.2%), mid-century (11.2-19.4%) and late-century (14.8-25.4%) timelines. In Peninsular Malaysia, the increments for early-century, mid-century and late-century were 3.5-8.0%, 7.8-11.9% and 8.9-12.5%, respectively. Among the regions, Region SW-3 in Sarawak may face the highest increment throughout the century. By the late-century, extreme high average annual rainfalls could be expected at Region SW-1 (4,619 mm) and Region SW-3 (4,336 mm) in Sarawak, and Region SB-3 (4,262 mm) in Sabah.

Figure 4.1: Projected Average Annual Air Temperature for the 13 Hydrological Regions in Malaysia

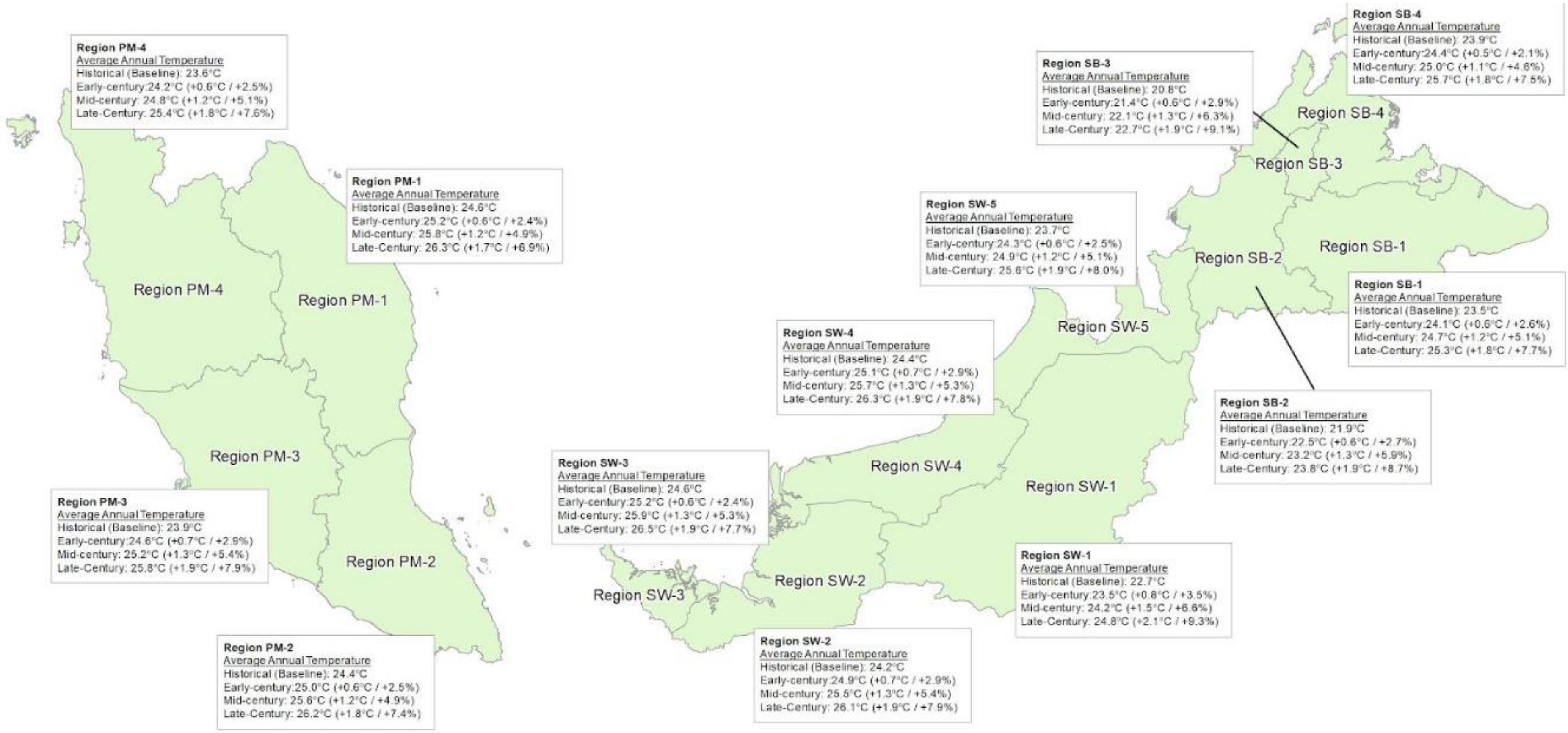
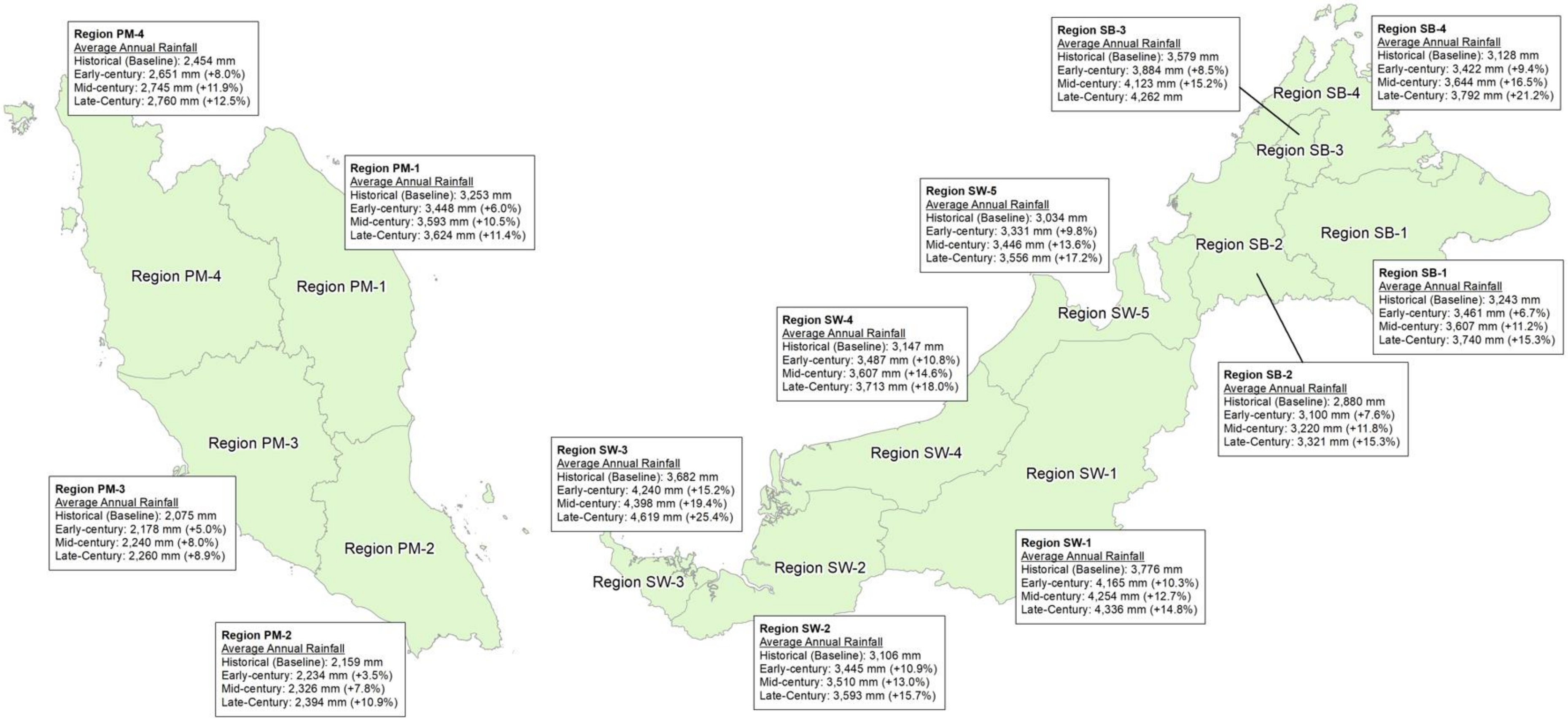


Figure 4.2: Projected Average Annual Rainfall for the 13 Hydrological Regions in Malaysia



4.4.3 Flood Areal Extent

There are 191 river basins in Malaysia, and of these, 144 river basins (86 in Peninsular Malaysia, 32 in Sabah and 26 in Sarawak) are prone to flooding. Detailed studies to quantify climate change impacts on flood areal extent has thus far, been conducted for 17 major flood areal extent basins in Peninsular Malaysia (Table 4.3 and Figure 4.3); 10 major flood prone basins in Sabah and 10 major flood prone basins in Sarawak (Table 4.3 and Figure 4.4). The total area of these river basins is about 232,002 km^2, which covers 70.3% of Malaysia's land area.

The flood assessments in Malaysia are based on flood extent maps associated with a 100-year Return Period for the time horizons projection of 2100. The assessments showed that the river basins in Peninsular Malaysia are more vulnerable to floods compared to those river basins in Sabah and Sarawak. The flood areal extent of the river basins in Peninsular Malaysia are anticipated to increase by 18.2% from the baseline timeline (1971-2000) to 2100. A smaller increase of 5.2% and 3.5% were projected for Sabah and Sarawak respectively, for the same time horizon.

Table 4.3: Projected Flood Areal Extent of 37 River Basins in Malaysia Associated with 100-Year Return Period

Flood Prone River Basins	Basin Area (km^2)	Simulated flood areal extent (km^2) at baseline timeline (1971-2000)	Projected flood areal extent up to 2100 (km^2)
Peninsular Malaysia			
Batu Pahat	2,233	237	297 (+25.4%)
Dungun	1,713	103	122 (+18.2%)
Johor	2,252	142	155 (+9.7%)
Kedah	3,627	213	248 (+16.4%)
Kelang	1,278	116	139 (+19.2%)
Kelantan	12,803	449	522 (+16.2%)
Kemaman	2,126	119	146 (+23.0%)
Kerian	1,475	107	142 (+33.7%)
Kesang	696	48	58 (+20.9%)
Kuantan	1,600	113	138 (+21.8%)
Linggi	1,328	63	74 (+18.1%)
Muar	6,033	426	490 (+15.0%)
Muda	4,114	213	242 (+13.8%)
Pahang	28,548	1,335	1,591 (+19.2%)
Perak	14,802	1,392	1,626 (+16.8%)
Selangor	2,086	188	227 (+20.9%)
Setiu	1,035	70	85 (+20.7%)
Sub-Total	*87,750*	*5,331 (6.1%)*	*6,299 (+18.2%)*
Sabah			

Flood Prone River Basins	Basin Area (km^2)	Simulated flood areal extent (km^2) at baseline timeline (1971-2000)	Projected flood areal extent up to 2100 (km^2)
Sg Kalumpang	**1,112**	**41**	**45 (+9.5%)**
Sg Padas	**8,822**	**475**	**476 (+0.2%)**
Sg Sinsilog	**927**	**49**	**55 (+12.1%)**
Sg Sugut	**3,067**	**244**	**245 (+0.2%)**
Trusan Kinabatangan	**16,233**	**603**	**641 (+6.3%)**
Sg Segama	**5,341**	**333**	**354 (+6.5%)**
Sg Tuaran	**1,147**	**14**	**16 (+17.6%)**
Sg Papar	**788**	**13**	**14 (+5.5%)**
Sg Labuk	**5,668**	**426**	**452 (+5.9%)**
Sg Abai	**862**	**29**	**28 (-3.1%)**
Sub-Total	**43,967**	**2,226 (5.1%)**	***2,341 (+5.2%)***
Sarawak			
Batang Rajang	**51,133**	**4,063**	**4,145 (+2.0%)**
Batang Baram	**22,109**	**1,383**	**1,511 (+9.2%)**
Batang Oya	**2,093**	**296**	**283 (-4.4%)**
Sg Sarawak	**1,727**	**204**	**224 (+9.3%)**
Batang Sadong	**3,527**	**316**	**324 (+2.5%)**
Batang Lupar	**6,511**	**500**	**489 (-2.2%)**
Sg Limbang	**3,916**	**81**	**84 (+3.5%)**
Batang Kemena	**6,028**	**243**	**261 (+7.4%)**
Batang Samarahan	**1,124**	**167**	**174 (+3.7%)**
Batang Saribas	**2,118**	**347**	**370 (+6.7%)**
Sub-Total	**100,285**	**7,601 (7.6%)**	***7,864 (+3.5%)***
TOTAL	**232,002**	**15,158 (6.5%)**	**16,504 (+8.9%)**

Under the future scenario, majority of the river basins in Peninsular Malaysia, except for Johor river basin and Muda river basin, could have more than 15% increment in their flood prone areas up to 2100, with Kerian river basin in Perak's increment possibly reaching 33.7 %. Other high risk river basins could include Batu Pahat river basin (+25.4 %), Kemaman river basin (+23.0 %), Kuantan river basin (+21.8 %), Kesang river basin (+20.9 %), Selangor river basin (+20.9 %) and Setiu river basin (+20.7 %).

In Sabah, the flood prone areas at Sg Kalumpang river basin, Sg Sinsilog river basin, Trusan Kinabatangan river basin, Sg Segama river basin, Sg Tuaran river basin, Sg Papar river basin and Sg Labuk river basin were projected to increase up to 2100 with the highest increment anticipated at Sg Tuaran river basin (+17.6%). In Sarawak, the situation could be more moderate as compared to Peninsular Malaysia and Sabah, where majority of the river basins could face less than 5% of increment except for Batang Baram river basin (+9.2%), Sg Sarawak river basin (+9.3%), Batang Kemena river basin (+7.4%) and Batang Saribas river basin (+6.7%).

Figure 4.3: Projected Flood Areal Extent of 17 River Basins in Peninsular Malaysia Associated with 100-Year Return Period

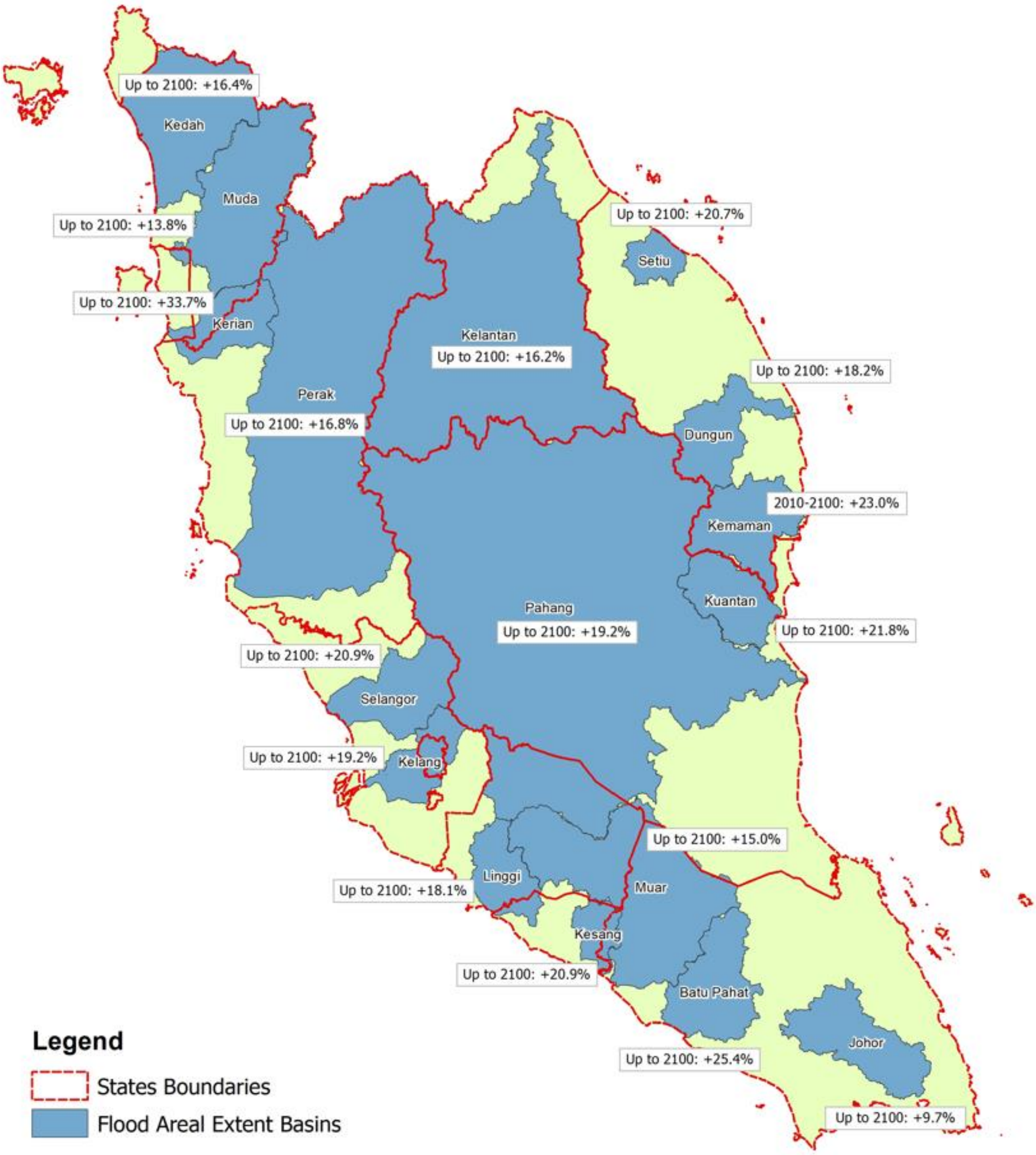
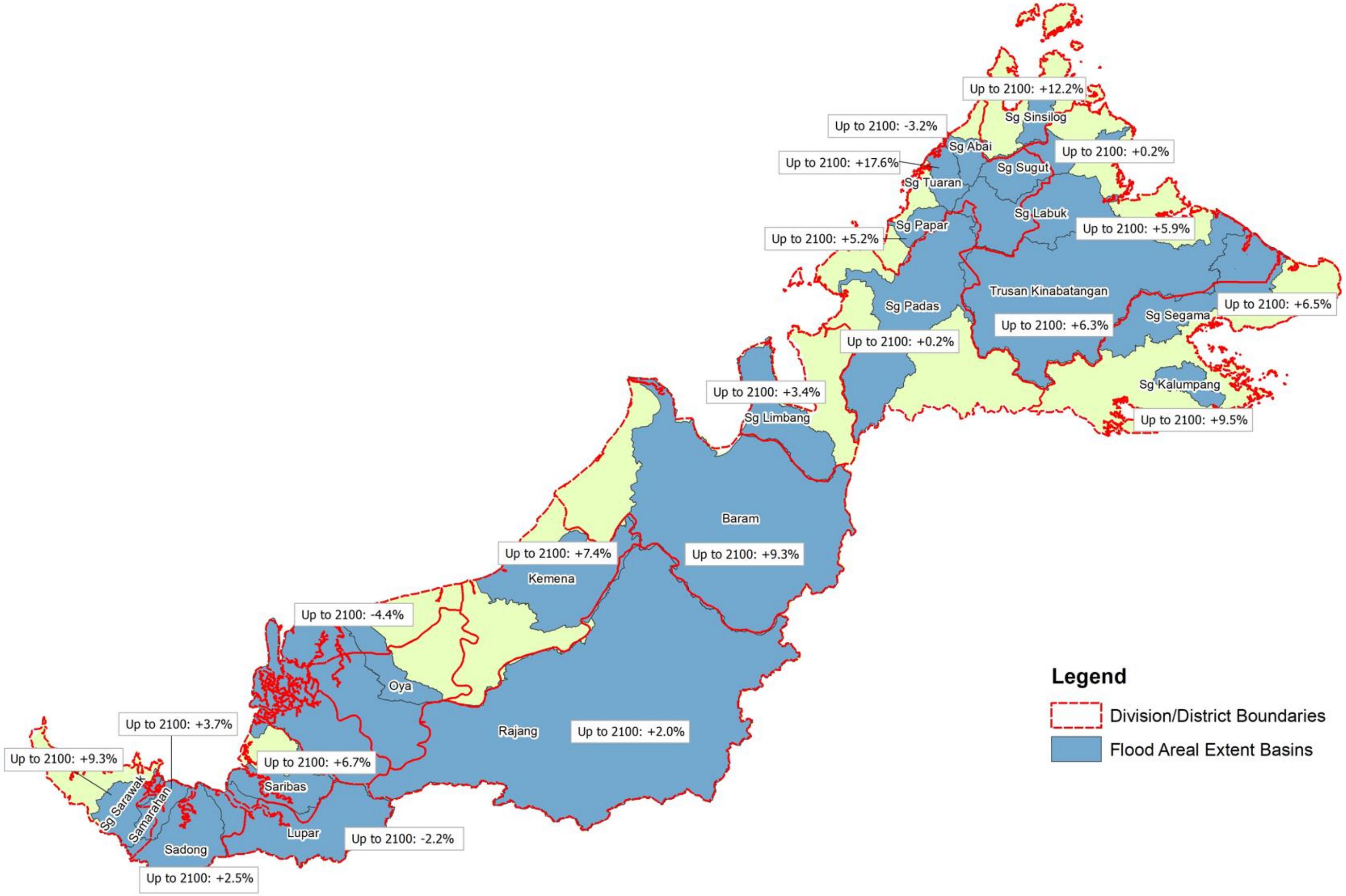


Figure 4.4: Projected Flood Areal Extent Of 20 River Basins in Sabah and Sarawak Associated with 100-Year Return Period



4.4.4 Dry Spells

Occurrences of dry spells had been analysed based on the projected annual rainfall up to 2050. The results are presented according to the river basins and regions in Figure 4.5, where the number of occurrences for each return period are shown with histograms. The occurrences of dry spells are indicated by return periods since the design safe yield for water supply is usually based on the 50-year return period. Although all the river basins and regions showed occurrences of dry spells, however the analysis showed that severe dry spells with return periods more than 50 years (up to 25.5% of annual rainfall reduction) could occur only at some of the river basins and regions with one or two occurrences.

The assessment of severities of dry spells with respect to a 50-year return period showed that the most severe dry spells could occur at regions of Coastal 10 and Coastal 11 in Peninsular Malaysia, where a reduction of more than 1,200 mm of rainfall is expected (Figure 4.6). Severe dry spells with annual rainfall reductions of 801-1,200 mm could occur at Coastal 12 region in Peninsular Malaysia. Moderate reductions of 401-800 mm annual rainfall are expected at Kemaman, Sadong, Saribas, Kadamaian and Southern Sabah. No rainfall reductions were projected at regions of Coastal 2, Coastal 3, Coastal 4 and Coastal 5 in Peninsular Malaysia. Projection results showed that the southern region and east coast of Peninsular Malaysia, and Sarawak, are subject to lesser reductions than other regions.

Figure 4.5: Projected Dry Spell Occurrences Based on Reduction in Annual Rainfall Associated with Return Periods for River Basins and Regions in Malaysia

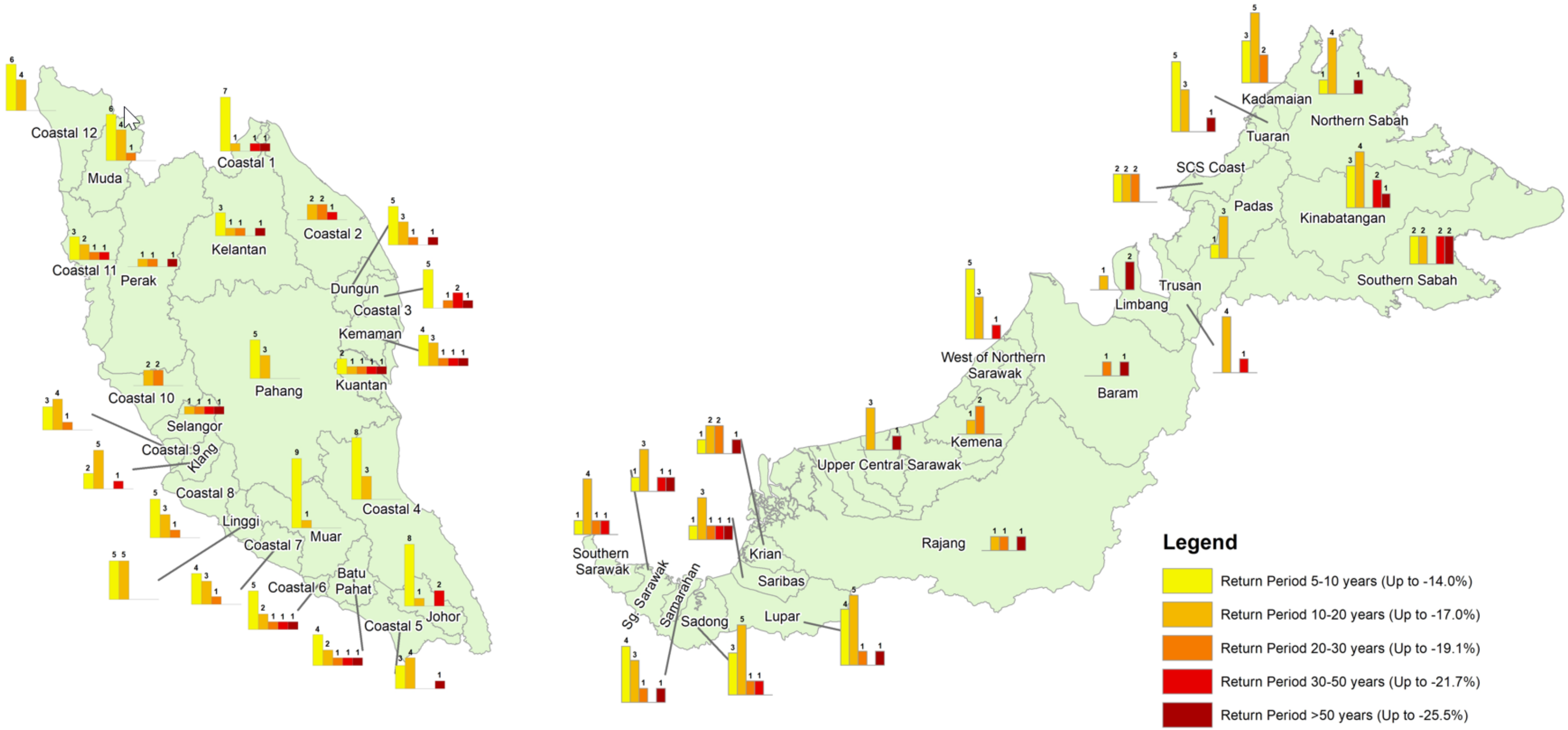
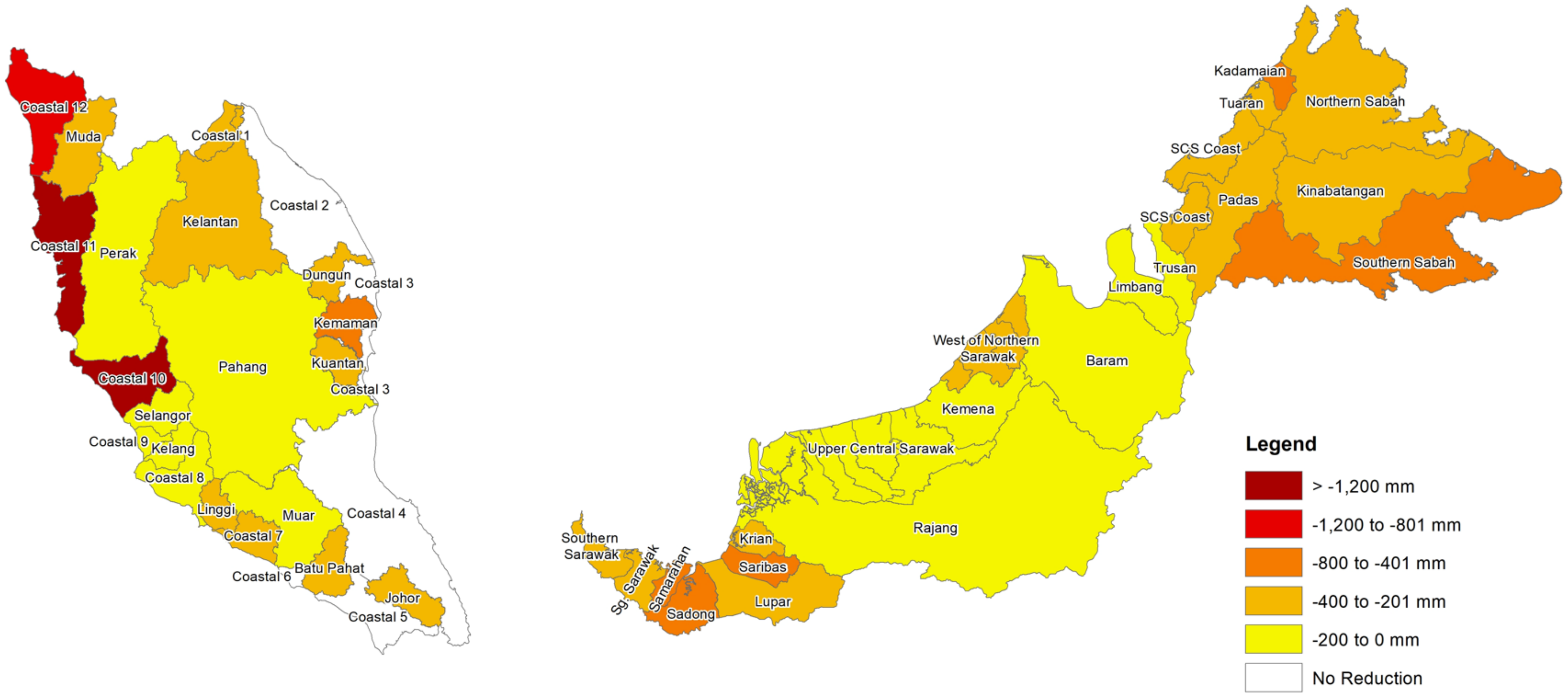


Figure 4.6: Projected Dry Spell Severities Based on Reduction in Annual Rainfall Magnitude Associated With 50-Yr Return Period for River Basins and Regions in Malaysia



4.4.5 Extreme Events

Extreme Dry Events

Dry events had been analysed based on the projected rainfall for the period of 2020-2100 (Figure 4.7). The rainfall variability index (RVI) was applied to indicate the severity of the dry spells. The analysis showed that extreme dry events could occur in Sabah in the early-century, where Region 7, Region 8, Region 9, Sg. Segama river basin, Sg. Kalabakan river basin and Sg. Kalumpang river basin would have RVIs between -3.01 and -4.00 corresponding to annual rainfall reduction of 26.6% to 38.6% respectively. Among these river basins, Region 8 was projected to be the most severely affected river basin with rainfall reduction of 1,247 mm from the baseline.

Very dry events with RVIs from -2.01 to -3.00 corresponding to annual rainfall reduction of 12.4% to 19.8% respectively could occur in Region 10 in Sabah, and Coastal 5, Coastal 6, Coastal 7, Coastal 9, Batu Pahat river basin and Johor river basin in Peninsular Malaysia, during the early-century and mid-century.

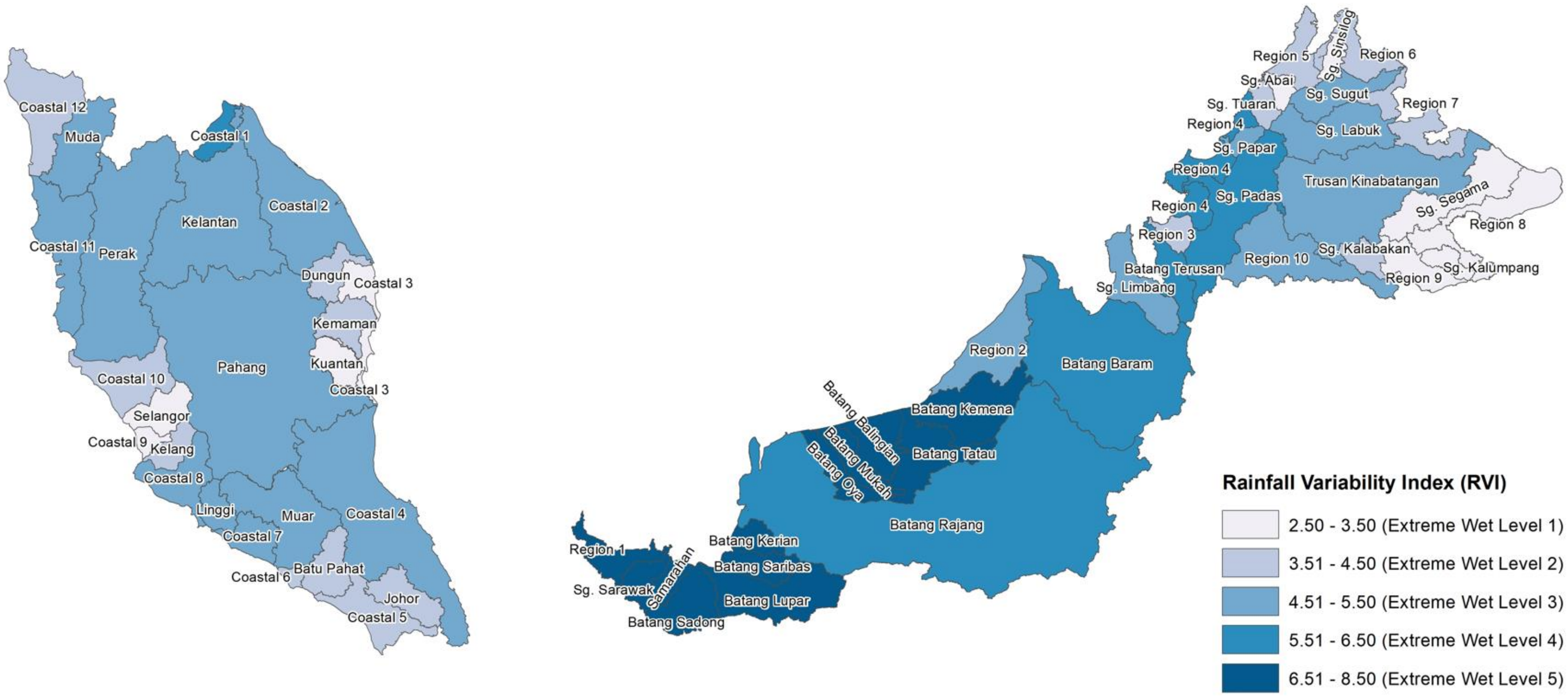
Extreme Wet Events

Wet events had been analysed using the same index and same period of projected rainfall. The analysis showed that extreme wet events (level 5) with RVIs ranging from +6.51 to +8.50 corresponding to annual rainfall increment of 42.5% to 62.6% respectively could occur at Batang Tatau river basin, Batang Samarahan river basin, Batang Lupar river basin, Batang Sadong river basin, Sg. Sarawak river basin, Batang Kemena river basin, Batang Balingian river basin, Batang Mukah river basin, Batang Kerian river basin, Region 1, Batang Oya river basin and Batang Saribas river basin in Sarawak (Figure 4.8). Other river basins such as Batang Baram river basin, Batang Terusan river basin and Batang Rajang river basin could have extreme wet events (level 4) with lower RVI from +5.51 to +6.50 corresponding to annual rainfall increment of 35.4% to 38.3% respectively. Similar situation could also occur in Region 4 and Sg. Padas river basin in Sabah, and Coastal 1 in Peninsular Malaysia.

The majority of the remaining river basins and regions in Peninsular Malaysia could experience extreme wet events (level 3) with RVI from +4.51 to +5.50 corresponding to annual rainfall increment of 23.4% to 53.0% respectively. The same is expected in Sg. Labuk river basin, Sg. Sugut river basin, Trusan Kinabatangan river basin, Sg. Papar river basin and Region 10 in Sabah, and Sg. Limbang river basin and Region 2 in Sarawak.

Figure 4.7: Projected Extreme Dry Events Based on RVI In Malaysia for The Period of 2020-2100

Figure 4.8: Projected Extreme Wet Events Based on RVI in Malaysia for the Period of 2020-2100



4.4.6 Climate Change Factor

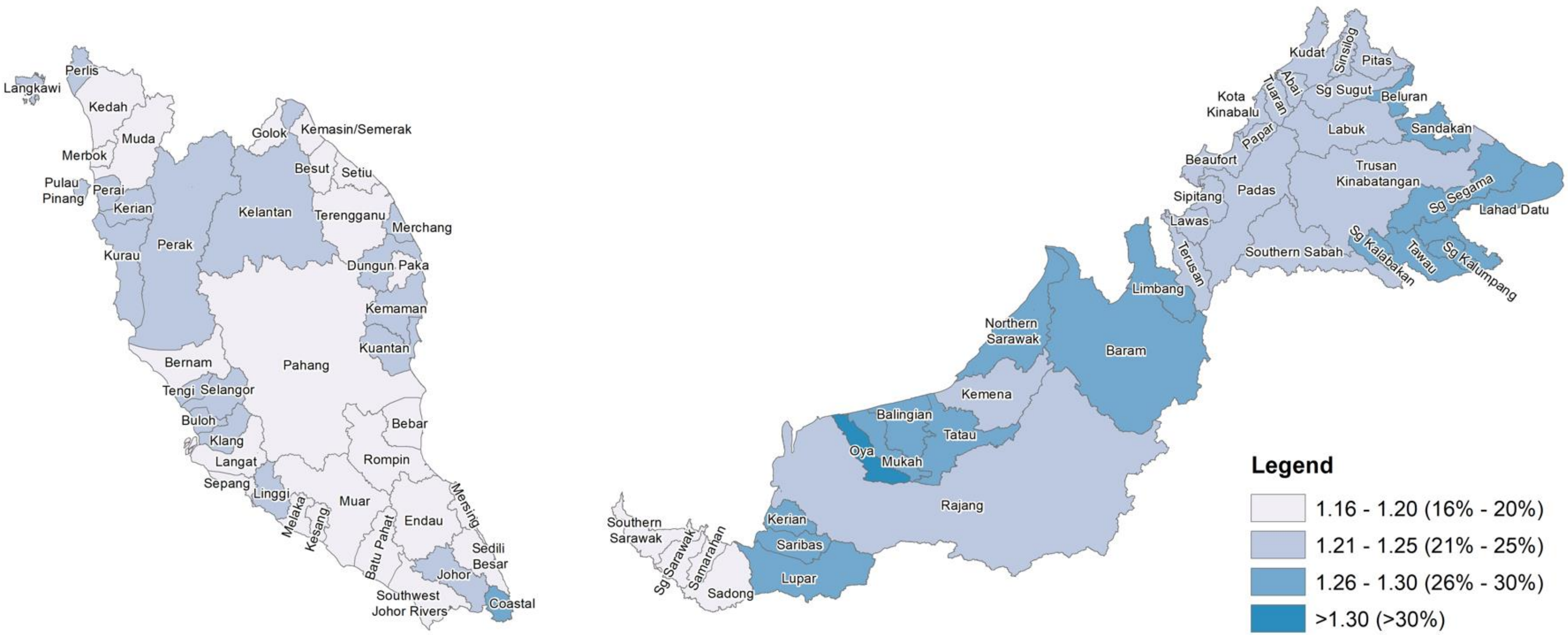
The conventional design capacity of water infrastructure system and components based on historical rainfall has become insufficient due to more extreme short and long duration rainfall intensity. In order to improve the adequacy of the design, a climate change factor (CCF) that quantifies the scale of rainfall intensity changes needs to be developed and applied. The CCF is defined as the ratio of the projected future design rainfall to the historical design rainfall.

CCFs have been developed based on annual maximum rainfall for each of the nine durations (0.25, 0.5, 1, 3, 6, 12, 24, 48 and 72-hour) with different return periods (2, 5, 10, 50 and 100-year) for 42 river basins in Peninsular Malaysia and 39 river basins in Sabah and Sarawak. The CCF for 1-hour and 24-hour rainfall durations with 100-year return period is shown in Figure 4.9. It was found that all the CCFs in Malaysia are greater than 1.00 with CCFs in Sabah and Sarawak slightly higher than those in Peninsular Malaysia.

In general, Sarawak is projected with higher percentage increments than in Sabah and Peninsular Malaysia. Among the 81 basins, Oya in Sarawak is the only basin projected with more than 30% of increment in future rainfall due to climate change. Other basins in Sarawak such as Mukah, Limbang, Baram, Northern Sarawak, Tatau, Balingian, Kerian, Saribas and Lupar also show a high increment of 26-30%. Coastal in Peninsular Malaysia and some basins in Sabah (Beluran, Sandakan, Sg. Segama, Lahad Datu, Sg. Kalumpang, Tawau and Sg. Kalabakan) also show the similar range.

In Sabah, all the remaining basins are projected to show percentage increments of 21-25%. The same percentage increments are also reflected in Sarawak (Lawas, Terusan, Kemena and Rajang) and Peninsular Malaysia (Johor, Linggi, Klang, Buloh, Tengi Selangor, Kurau, Perak, Kerian, Perai, Pulau Pinang, Perlis, Langkawi, Kelantan, Merchang, Dungun, Kemaman and Kuantan). Other basins in Sarawak and Peninsular Malaysia are expected to show 16-20% of increment only.

Figure 4.9: Calculated CCFs for 1-Hr And 24-Hr Rainfall Durations with Respect to 100-Yr of Return Period Based for Malaysia



4.4.7 Sea Level Rise

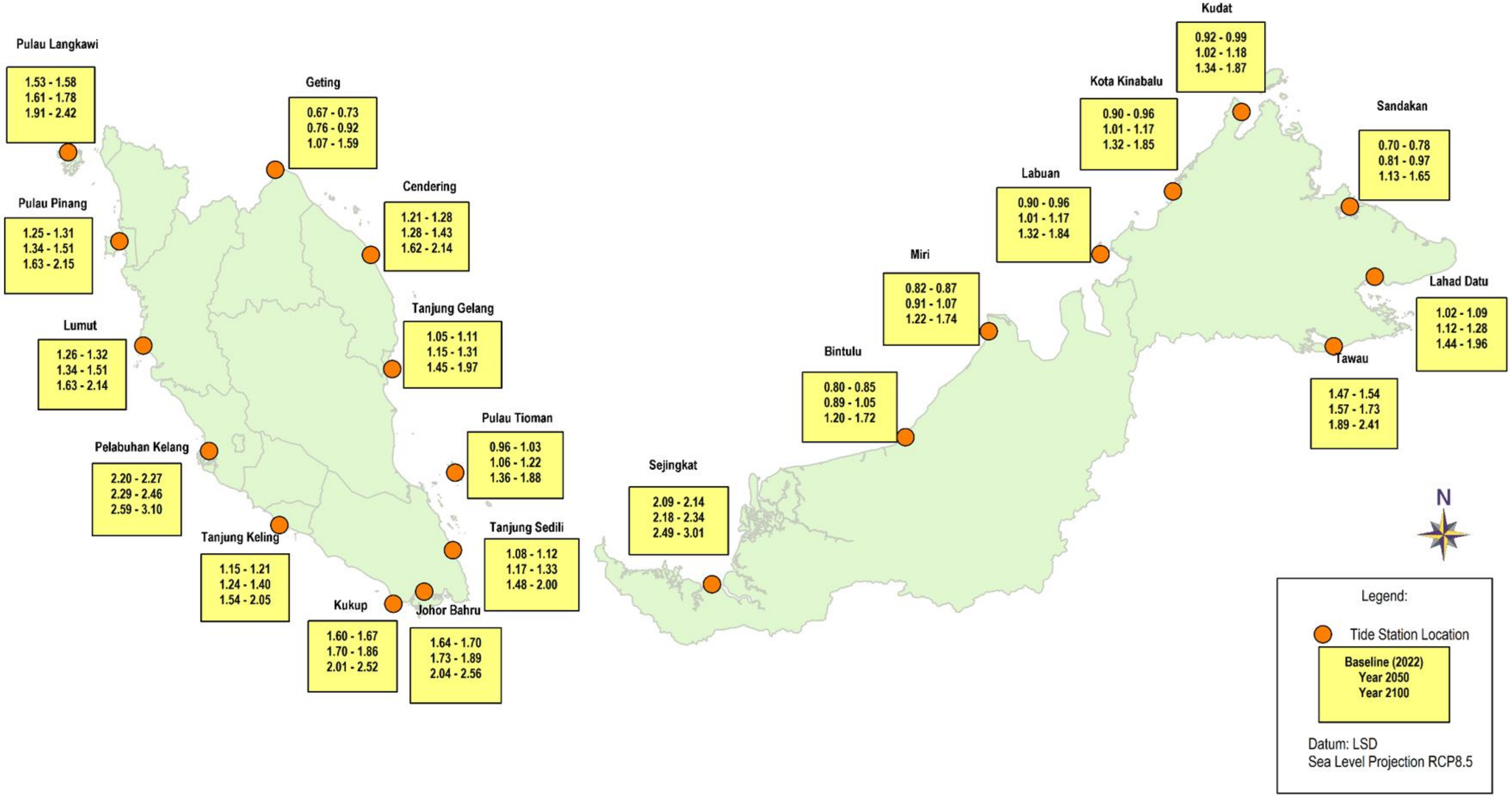
SLR was projected at selected tidal stations for the current timeline (2022), 2050 and 2100 with respect to sea level in 2015 as baseline (Table 4.4). The ranges of maximum sea level value were then estimated at the same stations for the same periods (Figure 4.10).

The Malaysian coastline was projected to face a maximum SLR of 0.25 m by 2050 and 0.74 m by 2100. Sabah is expected to have higher SLR than Sarawak and Peninsular Malaysia by 2050 and 2100, where the SLR up to 0.74 m could be faced at the Kudat coastline by 2100. Sarawak coastlines could have moderate values between the two. In Peninsular Malaysia, the west coast was projected with lower SLR impact than the east coast.

Table 4.4: Projected SLR at Current Timeline (2022), 2050 and 2100 in Malaysia

Tidal Station	Projected SLR (m)			Remarks
	Current timeline (2022)	2050	2100	
Pulau Langkawi	0.07	0.22	0.68	West Coast of Peninsular Malaysia
Pulau Pinang	0.07	0.22	0.68	
Lumut	0.07	0.22	0.67	
Pelabuhan Klang	0.07	0.22	0.68	
Tanjung Keling	0.07	0.23	0.69	
Kukup	0.07	0.23	0.70	
Johor Bahru	0.07	0.23	0.70	
Tanjung Sedili	0.07	0.23	0.70	East Coast of Peninsular Malaysia
Pulau Tioman	0.07	0.23	0.71	
Tanjung Gelang	0.07	0.23	0.71	
Cendering	0.07	0.23	0.70	
Geting	0.07	0.23	0.70	
Miri	0.07	0.24	0.72	Sarawak
Bintulu	0.07	0.24	0.71	
Sejingkat	0.07	0.24	0.72	
Labuan	0.07	0.24	0.73	Wilayah Persekutuan Labuan
Kota Kinabalu	0.07	0.25	0.73	Sabah
Kudat	0.08	0.25	0.74	
Sandakan	0.07	0.25	0.73	
Lahat Datu	0.07	0.24	0.73	
Tawau	0.07	0.24	0.72	

Figure 4.10: Projected Range of Sea Level Values (Metres) at the Selected Tidal Stations at Current Timeline (2022), 2050 And 2100 in Malaysia



4.4.8 Coastal Inundation

Coastal inundation along Malaysia shorelines was assessed and presented for the projected current timeline (2022), 2050 and 2100 (Table 4.5). The projected coastal inundation areas due to SLR along Malaysia coastline could increase from the current 5,255 km^2 to 6,144 km^2 and 9,295 km^2 by 2050 and 2100, respectively. The potential total inundated areas could increase by 16.9% and 76.9% by 2050 and 2100 respectively, compared to the current timeline. The most vulnerable coastline was projected to be located in Sabah, followed by Selangor in Peninsular Malaysia and Sarawak. The west coast of Peninsular Malaysia along the Straits of Malacca could be more vulnerable to coastal flooding compared to the east coast of Peninsular Malaysia.

Table 4.5: Projected Inundation Areas in Malaysia Coastlines at Current Timeline (2022), 2050 And 2100

State	Projected inundation area (km^2)		
	Current timeline (2022)	2050	2100
Perlis	12	17	53
Kedah	365	442	661
Pulau Pinang	122	156	319
Perak	751	858	1,186
Selangor	1,101	1,196	1,546
Negeri Sembilan	19	24	41
Melaka	25	32	73
Johor	814	897	1,166
Pahang	36	45	108
Terengganu	102	129	238
Kelantan	35	56	82
Sabah	1,511	1,771	2,512
Labuan	4	5	11
Sarawak	358	516	1,299
TOTAL	5,255	6,144	9,295

4.5 Water and Coastal Resources

4.5.1 Impact and Vulnerability

Reservoir Storage and Dam Security

In 2021, for Peninsular Malaysia and the Federal Territory of Labuan, almost 98.7% of potable water supply is from surface water sources, primarily through abstractions from run-of-river (81.9%), and direct abstractions from reservoirs (16.8%), while the remaining 1.3% is from groundwater. Based on the SPAN report on water supply dams, as of 2021, there were 55 dams which served as water supply dams. In addition, there were some 15 bund ponded storages and reservoirs augmenting water supply or river water flow for downstream water abstraction. There were also 23 dams serving the agricultural, and irrigation/drainage/flood mitigation functions.

Water supply and storage are significantly affected by extreme events such as floods and dry spells. Prolonged dry spells will lead to low reservoir storages, while heavier rainfall will result in higher reservoir water level that may affect the dam integrity, besides the fact that the inevitable release of excess water from the reservoirs may trigger downstream floods. According to the structural integrity assessment on the 104 dams by DID Malaysia in 2021, 40% of the dams are considered at high risk level (DID, 2022 data).

Floods (Extreme Wet)

Floods downstream of dams can occur when the water levels in the dam reach high levels due to continuous heavy precipitation resulting in inflow rates greater than the normal releases or extraction rate. In 2005 and 2017, downstream flood due to increased water release after heavy rainfall occurred at the Timah Tasoh Dam, Perlis. The town of Kangar was flooded due to the release of excess water from the dam. In 2017, the water levels of the dam were frequently above the normal levels. Under the future scenario, Timah Tasoh Dam at Coastal 12 was projected continues to face flood risk due to extreme wet weather throughout the century (Table 4.6). In general, there is no increment in terms of the number of vulnerable dams at all the basins and regions except for Batu Pahat River basin that shows an increment of two vulnerable dams by mid-century and Coastal 5 with five vulnerable dams by late-century. Coastal 4 and Muar are among the basins and regions with the highest number of vulnerable dams throughout the century. Figure 4.11 and Figure 4.12 show the locations of the water supply dams and hydropower dams which have been assessed.

Table 4.6: Projected Number of Water Supply Dams Affected by Extreme Wet Weather by Early-Century, Mid-Century and Late-Century in Malaysia

River basin / region	Projected number of water supply dams affected by extreme wet weather		
	By Early-century	By Mid-century	By Late-century
Peninsular Malaysia			
Coastal 2	**1**	**1**	**1**
Coastal 4	**7**	**7**	**7**
Coastal 5	**0**	**0**	**5**
Coastal 8	**2**	**2**	**2**
Coastal 9	**1**	**1**	**1**
Coastal 11	**3**	**3**	**0**
Coastal 12	**3**	**3**	**3**

River basin / region	Projected number of water supply dams affected by extreme wet weather		
	By Early-century	By Mid-century	By Late-century
Batu Pahat	0	2	2
Johor	3	3	3
Kelang	3	3	3
Kuantan	1	1	1
Linggi	3	3	3
Muda	2	2	2
Muar	6	6	6
Pahang	2	2	2
Perak	1	1	1
Selangor	2	2	2
Sub-Total	*39*	*39*	*43*
Sabah			
Region 4	1	1	1
Region 5	1	1	1
Region 7	1	1	1
Sg Segama	1	1	1
Sg Tuaran	1	1	1
Sub-Total	*5*	*5*	*5*
Sarawak			
Batang Sadong	1	1	1
Region 1	1	1	1
Region 2	1	1	1
Sub-Total	*3*	*3*	*3*
TOTAL	47	47	51

Figure 4.11: Location of water supply dams and hydropower dams vulnerable to extreme wet and/or extreme dry weather by early-century, mid-century and/or late-century in Peninsular Malaysia

Figure 4.12: Location of Water Supply Dams and Hydropower Dams Vulnerable to Extreme Wet and/or Extreme Dry Weather by Early-Century, Mid-Century and/or Late-Century in Sabah & Sarawak

Dry Spells

Some of the dams were affected with repeated dry spells in the past. A prolonged dry spell had resulted in low water levels at Sg Lebam Dam and Lok Heng Dam in Johor towards the end of February 2019. In June-November 2021, the water level in Lebam Dam again fell below critical level. In Melaka, the water levels at the Durian Tunggal Dam and Jus Dam were also observed to be below the critical levels for several months over two consecutive years (2019 and 2020). Some of the rapidly impacted dams include the Bukit Kwong Dam (2018 and 2021) in Kelantan and the Muda Dam (2018 and 2020) in Kedah, where the water level dropped below 50%. In 2021, SPAN identified dams at risk for water supply services based on physical dam performance, storage level and number of treatment plant in Peninsular Malaysia. There are 6 dams identified at high risk, 37 at medium risk and 15 at low risk (Table 4.7).

Table 4.7: List of Dams and Risk Level for Water Supply Services in Peninsular Malaysia (Source: SPAN, 2021)

Risk level	Number of Dams	State	Water Supply Dams
High (>70%)	6	Johor	Linggiu
		Kedah	Muda, Pedu
		Melaka	Durian Tunggal, Jus
		Pulau Pinang	Mengkuang,
Medium (50% - 70%)	37	Johor	Bekok, Congok, Gunung Ledang, Gunung Pulai 1, Gunung Pulai 2, Gunung Pulai 3, Juasseh, Labong, Layang (Lower), Layang (Upper), Lebam, Pontian Kecil, Sembrong
		Kedah	Ahning, Beris, Padang Saga (bunded storage)
		Melaka	Asahan
		Negeri Sembilan	Sg. Terip, Talang
		Pulau Pinang	Air Itam, Bukit Panchor,Teluk Bahang,
		Pahang	Chereh/Sg. Chereh, Kelau
		Perak	Bukit Merah, Sultan Azlan Shah/Sg Kinta
		Perlis	Timah Tasoh
		Selangor	Batu, Klang Gates, Langat, Tasik Subang, Sg. Tinggi, Semenyih, Sg. Selangor, Sg Tinggi, Tasik Subang
		Terengganu	Kenyir
Low (< 50%)	15	Johor	Kahang, Macap, Seluyut
		Kedah	Malut
		Negeri Sembilan	Gemencheh, Kelinchi, Pedas, Teriang, Ulu Sepri
		Pahang	Anak Endau, Pontian
		Perak	Air Kuning
		W.P. Labuan	Bukit Kuda, Kerupang, Sg. Pagar

Under the future scenario, 41 water supply dams in Peninsular Malaysia were projected to face extreme dry weather throughout the century except for the dam located at Coastal 9, which could only face extreme dry weather by mid-century (Table 4.8). In

Sabah and Sarawak, five water supply dams from each state were also identified to face the dry spell problems under the same timeline, except for early-century, where there could be only four dams from Sabah and three dams from Sarawak face similar impact.

Table 4.8: Projected Number of Water Supply Dams Affected by Dry Spells by Early-Century, Mid-Century and Late-Century in Malaysia

River basin / Coastal region	Projected number of water supply dams affected by dry spells		
	By Early-century	By Mid-century	By Late-century
Peninsular Malaysia			
Coastal 2	1	1	1
Coastal 4	7	7	7
Coastal 5	5	5	5
Coastal 7	2	2	2
Coastal 8	2	2	2
Coastal 9	0	1	1
Batu Pahat	2	2	2
Johor	3	3	3
Kelang	3	3	3
Kuantan	1	1	1
Linggi	3	3	3
Muar	6	6	6
Pahang	2	2	2
Perak	1	1	1
Selangor	2	2	2
Sub-Total	*40*	*41*	*41*
Sabah			
Region 4	1	1	1
Region 5	1	1	1
Region 7	1	1	1
Sg Segama	1	1	1
Sg Tuaran	0	1	1
Sub-Total	*4*	*5*	*5*
Sarawak			
Batang Lupar	0	1	1
Batang Rajang	2	2	2
Batang Sadong	0	1	1
Region 2	1	1	1
Sub-Total	*3*	*5*	*5*
TOTAL	47	51	51

Flood Risk Management

According to DID Malaysia, the country is exposed to approximately 144 flood events, on an annual average. The consequence of these fluvial, monsoonal, coastal, and flash floods is that about 33,298 km^2 (10.1%) of the country land areas with 5.7 million of people (21% of the population) are affected.

Floods

In 2022, NRES (formerly KASA) through DID Malaysia has identified 5.496 flood hotspots over the country to alert the public who lives in these areas to potential flood disasters (Table 4.9). With climate projections indicating that more frequent and extreme rainfall events associated with pluvial flooding may occur in the country, the assessments on flood impacts and vulnerability can offer suitable adaptation measures, particularly at these identified flood hotspots.

Table 4.9: Flood Hotspots in Malaysia by State and Federal Territory

State / Federal Territory	Number of Flood Hotspot
Sarawak	**1,034**
Pahang	**763**
Kelantan	**595**
Sabah	**520**
Johor	**432**
Kedah	**373**
Negeri Sembilan	**369**
Selangor	**339**
Terengganu	**300**
Perak	**265**
Pulau Pinang	**229**
Melaka	**157**
Perlis	**54**
Kuala Lumpur	**48**
Putrajaya	**0**
Labuan	**18**
TOTAL	**5,496**

Based on the flood areal extent projections for the 232,001 km^2 of flood prone river basins and regions in Malaysia, around 15,158 km^2 (6.5%) of these flood prone river basins and regions were vulnerable to floods at baseline timeline (1971-2000), as shown in Table 4.3. These large projected flood prone areas tallied with the high number of 5,496 flood hotspots identified throughout the entire country (Table 4.9). Sarawak, which has the highest number of flood hotspots of 1.034, also has the largest flood prone areas of 7,601 km^2 (7.6% of the total flood prone river basins and regions) at baseline timeline (1971-2000) and 7,864 km^2 (7.8% of the total flood prone river basins and regions) up to 2100 (Table 4.3).

Sea Level Rise

Coastal flooding due to SLR was projected to increase the vulnerability of the coastal community. According to the impact assessment on coastal floods based on the projected coastal inundation areas by 2100 carried out for Peninsular Malaysia and

Labuan, there is around 16.6 million of people could be affected by coastal floods due to SLR by 2100. The number of affected populations was estimated based on an annual population growth of 1.3% taking 2021 as baseline.

Groundwater Security

There are currently 2,017 tube wells in Malaysia. Most of the wells serve as production wells for agricultural, domestic, industrial and mixed uses, with the rest serving as monitoring wells. At present, the water supply from groundwater sources in Peninsular Malaysia is estimated to be 354,420 m^3 per day (0.2%), while around 10.3 million m^3 per day is from surface water. Kelantan records the highest groundwater use among the states with 58% of its clean water supply from the aquifers.

Sea Level Rise

Continuous groundwater level and quality monitoring at some selected deep seated tube wells is important and being conducted by the Department of Minerals and Geosciences (DMG) Malaysia. Saltwater intrusion and coastal inundation due to SLR is a risk to groundwater quality. In addition, over-extraction could result in increased saline intrusion for wells located nearer to the coast.

There were 40 tube wells located in Pulau Pinang, Johor, Kelantan, Selangor, Terengganu, Melaka, Perak, Kedah, Sabah and Sarawak projected to be vulnerable to saltwater intrusion at current timeline (2022), as shown in Table 4.10. The preliminary assessment indicated that 44 and 68 tube wells could be affected by saltwater intrusion by 2050 and 2100, respectively. Among the states, Selangor (26 tube wells), Perak (11 tube wells) and Sabah (9 tube wells) show a high number of vulnerable tube wells by 2100.

Table 4.10: Projected Number of Tube Wells Affected by Saltwater Intrusion Due to SLR at Current Timeline (2022), 2050 and 2100 in Malaysia

State / Federal Territory	No. of tube well available	Projected number of tube wells affected by SLR		
		Current timeline (2022)	2050	2100
Johor	129	1	1	4
Kedah	155	1	1	2
Kelantan	218	4	4	4
Melaka	102	0	1	1
Negeri Sembilan	164	0	0	0
Pahang	132	0	0	0
Perak	114	9	9	11
Perlis	18	0	0	0
Pulau Pinang	12	0	0	1
Selangor	444	14	17	26
Terengganu	105	3	3	7

State / Federal Territory	No. of tube well available	Projected number of tube wells affected by SLR		
		Current timeline (2022)	2050	2100
Sabah	**193**	**6**	**6**	**9**
Sarawak	**231**	**2**	**2**	**3**
Federal Territories	**0**	**Not assessed**	**Not assessed**	**Not assessed**
TOTAL	**2,017**	**40**	**44**	**68**

Coastal Erosions

Malaysia has a coastline of over 8,840 km covering a total of 44,200 km^2 coastal zone (13.5% of the country's total land area). Of this coastline, 1,348 km (55.4 km under critical erosion category, 376.1 km under significant erosion category and 916.5 km under acceptable erosion category) covering a total of 3,693 km^2 of coastal zone is currently exposed to potential erosion threat as reported in NC3. No substantial increment of coastlines and coastal areas exposed to potential erosion threat was reported since then. This could be due to the adaptation measures that had been taken.

Sea Level Rise

Coastal erosion could be worsened by SLR through inundation. SLR can result in potentially adverse impacts of coastal flooding, accelerated coastal erosion and land subsidence. SLR is ultimately responsible for long-term coastal erosion problems.

Based on the assessment along the 3,800 km of coastline in Peninsular Malaysia and Federal Territory of Labuan using the Physical Coastal Vulnerability Index (PCVI) adapted in the revised National Coastal Vulnerability Index (NCVI) 2021, Selangor could be the most vulnerable state with almost 80% of its coastal areas exposed to the threat of erosion. Other vulnerable coastal areas could also be found in Pahang, Kedah (including Langkawi), Perak, Johor and Federal Territory of Labuan.

Under the future scenario, along the coastlines of Peninsular Malaysia, an average increment of 0.22 m to 0.23 m in sea level was projected by 2050, further increasing to 0.67 m to 0.71 m by 2100. The coastal inundation estimated based on these SLR projections showed that the west coast shorelines along Perlis, Kedah, Pulau Pinang, Perak, Selangor and west coast of Johor could be more vulnerable compared to the east coast shorelines of Peninsular Malaysia by 2100. However, the low-lying delta areas of the Kelantan River in the east coast is also likely to be inundated should the SLR be 0.70 m by 2100.

In Sabah, high SLR projections along the Kudat-Sandakan coastline with magnitudes of 0.73 m to 0.74 m by 2100 have indicated the need for further assessments of potential coastal erosion along the coastline.

In Sarawak, the projected increment of 0.71 m to 0.72 m along the Miri-Bintulu and Bintulu- Sejingkat coastlines by 2100 could affect the lower-lying areas around the deltaic complexes of Sg Sarawak, affecting Petra Jaya; the Rajang delta islands, and the smaller river mouths along the east towards Miri.

4.5.2 Adaptation Measures

Policies, Frameworks and National Plans

The National Water Policy (NWP), which is in the final stage of preparation, is one of the key milestones towards a more sustainable and integrated management of water resources in the country in order to face the challenges posed by climate change. This policy will replace the National Water Resources Policy 2012. The National Climate Change Policy 2009, which is being revised, is another policy on climate change that aims to strengthen the institutional and implementation capacity to better harmonise opportunities to reduce negative impacts on climate change, including water resources in the country.

Under the 12th Malaysia Plan, the Development of the Road Map for the National Agenda on Water Sector Transformation 2040 (WST 2040) Study has been completed by the government as a national agenda to transform the water sector into a dynamic & vibrant economic sector that can contribute significantly to the national GDP & provide good quality affordable water, as well as create new job opportunities. It ensures that impact of climate-related hazards are considered in water-related development plans, and is continued to be fulfilled beyond 2040 through the four waves of transformation embedded in the four Malaysian Plans from 2021 to 2040.

To support WST 2040, a Climate Change Adaptation Framework for Water Sector has been developed by the government through NAHRIM in 2021. This framework also aims to facilitate the formulation of sound policies and best practices that support sustainable water management and ensure water security, especially in dealing with climate change impacts.

Water Resources and Dam Security

The Fourth National Physical Plan (NPP4) 2020 highlighted the need for planning for sustainable water uses in the context of climate change. Among others, this has been done through the Integrated Water Resources Management (IWRM) that promotes the coordinated development and management of water, land and related resources, and the Integrated River Basin Management (IRBM) that supports the relevant state water authorities in the management of their resources.

Since the NC3, the protection of dam water catchment areas had been implemented to ensure adequate water storage inflow into the dam reservoirs. There are around 170 permanent reserved forests already gazetted as water catchment areas in the country. There is also a plan to gazette more of these forests in order to secure and enlarge the reservoir storage.

The National Water Balance Management System (NAWABS), which acts as a water management tool and uses the water balance concept to inform on water availability for the purpose of planning and operational decision-making during droughts and dry periods, has its first phase implemented and completed at the Kedah River basin, Muda

River basin, Bernam River basin, Melaka River basin and the Kelantan River basin in 2020 to test its efficacy. This program offers a quantitative approach to raw water distribution and water savings efforts to improve water resources and supply services, reservoir storage and dam security, particularly concerns during extreme dry spells arising from climate change impact. This is supported by a national hydrological monitoring programme and network, whereas of 2021 a total of 99 river water level, 626 rainfall stations and 455 combination (rainfall and water level) stations along the river basins had been installed, as well as a drought information monitoring website (InfoKemarau).

With regards to the dam safety issues due to the dam structures and extreme rainfall at the water catchment areas, the Malaysia Dam Safety Management Guidelines (MyDAMS) established in 2017 is being used to monitor to ensure the safety of dams. The use of these guidelines is currently monitored by the Special Committee for Safety Management of Dam Structures under the Ministry of Environment and Water. The MyDAMS is an important move to enhance operator knowledge and capacity for managing the safety of dams, especially for new dams under the changing climate scenarios. The development of legislation on dam management and operation is the next step in the works.

The main dam embankment and saddle dam of the Timah Tasoh Dam had been raised under the dam upgrading projects by DID Malaysia. The upgrade will help overcome the flood problem in the downstream area of the dam, such as at Bandar Kangar and nearby areas, by increasing the capacity of the flood reservoir in addition to increasing domestic and industrial water supply sources. Other dam upgrading projects include the Bekok Dam in Batu Pahat, Johor, which is the sole water source for Batu Pahat and Yong Peng areas. Vibrant and increasingly rapid development has caused the demand for raw water supply to rise in these areas, especially during the dry spell periods in the last decade. Dam upgrading works were also conducted at the Bukit Merah Dam and the Gopeng Dam in Perak, and will be conducted for the Padang Saga Dam in Langkawi as well.

Flood Risk Management

In Malaysia, the development of flood mitigation plans and infrastructure projects has been one of the consistent approaches by DID Malaysia to relieve the population from the effects of heavy rainfall and runoff. Currently, there are 76 flood mitigation projects being implemented throughout the country, while 32 and 13 projects are respectively, under planning and study, respectively. There are 60 hazard maps having been developed between 2010 and 2022 at different river basins, to support these projects.

The DID Malaysia has also installed a network of telemetric rainfall and river water level stations to monitor the rainfall and river water levels at the major river basins to help in flood forecasting and monitoring work. Recently, this implementation has been expanded to cover the smaller rivers as well. The National Flood Forecasting and Warning Programme (NaFFWS) was initiated and aims to develop a system to forecast monsoon flood, and forecast and disseminate flash flood warning, based on weather forecast data from the Malaysia Meteorological Department (MMD).

Following the flood of debris at Jerai and Baling in Kedah, and Janda Baik in Pahang, the sabo structure has been introduced to protect the properties, public, as well as government assets from the impact of destruction due to debris floods. The sabo structure is a structure designed to slow down the water current from uphill to lower river streams, as well as to trap logs, huge rocks and debris during a water-surge phenomenon. Apart from the pilot projects in Kedah and Pahang, a total of 52 sabo structure construction projects will be implemented as a long-term preventive measure in Kedah, Perak, Selangor, Negeri Sembilan, Johor, Pahang, Terengganu, Kelantan, Sabah and Sarawak.

Groundwater Security

Even though surface water is the main water source in Malaysia, groundwater is now considered a significant supplementary water supply resource in areas with water supply problems. Among the states, Kelantan has the highest number of production wells since it is one of states with the highest groundwater consumption in Malaysia. To support water supply sustainability, especially during the prolonged dry spells, DMG has initiated a few programmes for the development of groundwater resources in some water stressed areas in the country. By 2022, there are 224 tube wells developed (11.1% of the tube wells in use) for this purpose.

To support water supply availability under NAWABS, DMG has a program to monitor the groundwater levels of the tube wells located at the Kelantan River Basin, Similajau River basin, Klang River basin, Melaka River basin and the Muda River basin. The second phase of the monitoring program has been initiated at Padas River basin, Perak River basin, Muar River basin and Pahang River basin. As reported in 2021, a total of 614 tube wells (30.4% of the tube wells in use) were being monitored.

Apart from ensuring groundwater availability, groundwater quality is the other area of concern. Under the Hydrogeological Mapping and Groundwater Development Project initiated in Kedah, a groundwater quantity and quality monitoring well would be installed with a telemetry system to measure parameters such as conductivity, water level, temperature, total dissolved solids and salinity. Through this project, early warning can be given when the groundwater quality does not meet the set quality standards due to prolonged dry spells, so that the pumping rate can be slowed down or stopped.

Coastal Erosions

To ensure sustainable coastal developments, DID Malaysia has carried out studies and developed the Integrated Shoreline Management Plan (ISMP), which include assessing the risks of coastal erosions. These plans are designed to support the State development and implement adaptive measures including those arising from climate change. At the moment, 16 ISMPs have been completed covering 12 states and 1 federal territory that represent 33% of the Malaysian coastline. Since 2020, SLR impact has been taken into consideration in five ISMP studies.

Under the Coastal Erosion Control Programme that had started in 2016, several coastal infrastructure projects were implemented for the conservation and repairing works along the shorelines by DID Malaysia. As of December 2020, 26.54 km (88.5%) of the targeted 30 km length had been achieved. Some of the important and major completed projects include the repairing of infrastructures at 31 locations with an approximate total length of 6.4 km along the coastlines of Perlis, Sarawak, Kelantan, Melaka and Selangor completed in 2019. In Terengganu, an approximate 6 km of erosion control and protection work at various locations have been implemented from 2016 to 2019.

4.6 Agriculture and Food Security

4.6.1 Impact and Vulnerability

Rice

Currently, the country has a rice self-sufficiency of 71.6%. The Ministry of Agriculture & Agro-based Industry targeted a self-sufficiency level (SSL) of 80% by 2030 under The Malaysia's National Agrofood Policy 2021-2030 (NAP 2.0).

In 2019, the total rice planted area in the country was 672,084 ha with a net production of 1,516,341 metric tonnes of rice (Table 4.11 & Table 4.12). Around 77.3% of the planted area was in Peninsular Malaysia, while 22.7% was in Sabah and Sarawak. Kedah accounted for 31.9% of the total planted area followed by Perak (12.1%), Kelantan (10.6%), Perlis (7.7%) and Selangor (5.4%).

Table 4.11: Rice Planted Area (Hectares) in Malaysia

Year	2000	2005	2010	2016	2017	2018	2019
Peninsular Malaysia	518,927	499,488	512,610	522,826	522,678	522,112	519,277
Sabah	48,894	40,117	43,353	41,733	42,157	42,442	43,546
Sarawak	130,881	127,218	121,921	124,211	120,713	135,426	109,261
TOTAL	698,702	666,823	677,884	688,770	685,548	699,980	672,084

Source: Paddy Statistics of Malaysia 2010, Booklet Statistik Tanaman 2021

Table 4.12: Rice Production (Metric Tonnes) in Malaysia

Year	2000	2005	2010	2016	2017	2018	2019
Peninsular Malaysia	1,202,098	1,259,696	1,312,132	1,545,412	1,438,629	1,463,445	1,316,128
Sabah	97,668	94,259	147,531	72,953	69,890	77,106	70,919
Sarawak	81,896	136,060	128,793	143,750	147,783	159,215	129,294
TOTAL	1,381,662	1,490,015	1,588,456	1,766,115	1,656,302	1,699,766	1,516,341

Source: Paddy Statistics of Malaysia 2010, Booklet Statistik Tanaman 2021

In Malaysia, granaries are those with major irrigation scheme areas greater than 4,000 ha, and recognized as the main rice producing areas. The 12 main granary areas have a total planted area of 422,066 ha with 1,211,809 metric tonnes of rice production in 2019 (Table 4.13). They are located in low-lying coastal plains and depend on irrigation for the expectant annual double rice cropping.

Table 4.13: Rice Planted Area and Production in 2019 for the 12 Granary Areas in Malaysia

Granaries	Planted area in 2019 (ha)	Production in 2019 (metric tonnes)
MADA	201,338	645,584
KADA	50,346	131,958
IADA KERIAN	41,898	97,605
IADA Barat Laut Selangor (BLS)	36,602	113,158
IADA Pulau Pinang	25,564	83,282
IADA Seberang Perak	27,334	51,925
IADA KETARA	9,752	32,718
IADA Kemasin Semerak	7,564	18,351
IADA Pekan	6,634	11,372
IADA Rompin	5,108	7,878
IADA Kota Belud (Sabah)	8,803	16,126
IADA Batang Lupar (Sarawak)	1,121	1,852
TOTAL	422,066	1,211,809

Source: Booklet Statistik Tanaman 2021

Crop Yield Assessment

Assessment of the MARDI Siraj 297 crop yield in MADA based on the projected temperature, rainfall and solar radiation was also carried out at these granaries for early-century, mid-century and late-century. The average projected yield for the main season could be reduced by 27.0% by late-century compared to the baseline yield of 4,933 kg per ha in 2019. The off-season yield could also be reduced by 30.1% for the same future period.

Reduction in yield is also envisaged at KADA. Compared to the baseline yields of 4,032 kg per ha in 2019, the projected average yield for the main season and off-season could be reduced by 39.2% and 7.2%, respectively, by late-century. For the same future period, at the IADA Barat Laut Selangor, the main season and off-season yields were projected reduced by 16.0% and 24.7%, respectively.

Floods

Although rice is cultivated under irrigated conditions, most of the rice varieties would not be able to survive if exposed to prolonged total submergence. Studies by MARDI found that rice is most susceptible to flood if it occurs during early planting but still can recover if the flood or submergence occurs not more than 7 days during the vegetative stage.

The parcel areas that were assessed to be prone to floods at baseline timeline (1971-2000) were also projected to continue to be affected by floods up to 2100 (Table 4.14). The parcel areas in Kerian and Yan were projected to be the most vulnerable areas with 14,275 ha and 18,075 ha, respectively, possibly facing floods up to 2100. The other projected vulnerable areas up to 2100 were at Pasir Mas (5,633 ha), Seberang Perai Selatan (2,624 ha) and Lipis (2,516 ha). Flood depths up to 4.51 m and 3.42 m were projected at Lipis and Seberang Perai Selatan.

Table 4.14: Projected Flood Prone Rice Parcel Areas at Baseline Timeline (1971-2000) and up to 2100 in Peninsular Malaysia

District	State	Total Parcel Area (ha)	Projected flood prone parcel area with average flood depth					
			Baseline timeline (1971-2000)			Up to 2100		
			Parcel Area (ha)	%	Ave. Flood Depth (m)	Parcel Area (ha)	%	Ave. Flood Depth (m)
Pasir Mas	**Kelantan**	**56,566**	**3,960**	**7**	**1.44**	**5,633**	**10**	**1.67**
Yan	**Kedah**	**129,237**	**15,241**	**12**	**1.82**	**18,075**	**14**	**2.22**
S. Perai Selatan	**Pulau Pinang**	**14,446**	**2,419**	**17**	**2.86**	**2,624**	**18**	**3.42**
Kerian	**Perak**	**46,047**	**11,365**	**25**	**1.84**	**14,275**	**31**	**2.22**
Alor Gajah	**Melaka**	**1,861**	**143**	**8**	**1.22**	**199**	**11**	**1.48**
Kemaman	**Terengganu**	**12,759**	**1,082**	**8**	**2.12**	**1,190**	**9**	**2.58**
Lipis	**Pahang**	**10,267**	**2,486**	**24**	**3.24**	**2,516**	**25**	**4.51**
Kuala Pilah	**N. Sembilan**	**1,633**	**295**	**18**	**2.68**	**301**	**18**	**3.26**
Tangkak	**Johor**	**1,739**	**492**	**28**	**1.21**	**599**	**34**	**1.68**
Barat Laut	**Selangor**	**21,172**	**0**	**0**	**0**	**0**	**0**	**0**
Wilayah MADA1	**Perlis**	**28,903**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL / AVERAGE		**324,630**	**37,483**	**14.7**	**1.84**	**45,412**	**17.0**	**2.30**

Dry Spells

A prolonged dry spell may have a direct impact on rice plant growth and production. In early 2020, at least 36% of the total production area of KADA, MADA and IADA Penang were affected by the prolonged dry spell, which occurred from November 2019 to February 2020. A risk assessment of potential dry spells projected by decades up to 2050 was carried out for KADA, MADA, IADA BLS and IADA KERIAN. KADA is anticipated to be the most affected granary with projected dry periods from mid-decade of 2020s to late-decade of 2040s (Table 4.15). This is followed by the IADA BLS, MADA and then IADA KERIAN. Among the projected dry periods of the four granaries, extra attention should be given to the mid-decade of 2020s, early-decade of 2030s and late-decade of 2040s, as these are the projected dry periods at all these four granaries.

Table 4.15: Projected Dry Periods (by Decades) at the Four Main Rice Granary Areas (Parcel Areas) By 2050

Granary	Projected dry periods by decades			
	Decades	By early-decade	By mid-decade	By late-decade
MADA	2020s	✓	✓	
	2030s	✓		✓
	2040s			✓
KADA	2020s		✓	✓
	2030s	✓	✓	✓
	2040s	✓	✓	✓
IADA BLS	2020s		✓	✓
	2030s	✓	✓	✓
	2040s			✓
IADA KERIAN	2020s	✓	✓	
	2030s	✓		
	2040s			✓

Sea Level Rise

The granaries located in the low-lying coastal plains are vulnerably exposed to SLR and coastal inundation. Assessment of rice production areas in Kedah (MADA) indicated that 27,417 ha or 21.2% of the areas could be inundated by seawater by 2050 (Table 4.16). The inundation could further increase to 44,204 ha (34.2%) by 2100. More severe inundation up to 13,321 ha (62.9%) and 16,763 ha (79.2%) into the rice cultivated areas are expected by 2050 and 2100, respectively, in Selangor IADA BLS. Other vulnerable parcel areas are located in Perak and Pulau Pinang. Overall, the total rice parcel areas in Peninsular Malaysia that could be affected by SLR were projected to be 57,523 ha (17.7%) and 88,916 ha (27.4%) by 2050 and 2100, respectively.

Table 4.16: Projected Rice Parcel Areas Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State	Total Parcel Area (ha)	Current timeline (2022)		2050		2100	
		Projected Parcel area (ha)	%	Projected Parcel area (ha)	%	Projected Parcel area (ha)	%
Johor	1,739	453	26.1	476	27.4	536	30.8
Kedah	129,237	21,651	16.8	27,417	21.2	44,204	34.2
Kelantan	56,566	937	1.7	2,055	3.6	3,174	5.6
Melaka	1,861	36	1.9	53	2.9	129	6.9
N. Sembilan	1,633	0	0.0	0	0.0	0	0.0
P. Pinang	14,446	1,069	7.4	1,949	13.5	4,484	31.0
Pahang	10,267	17	0.2	26	0.3	827	8.1
Perak	46,047	9,436	20.5	10,948	23.8	14,402	31.3
Perlis	28,903	596	2.1	966	3.3	3,652	12.6
Selangor	21,172	12,194	57.6	13,321	62.9	16,763	79.2
Terengganu	12,759	224	1.8	311	2.4	745	5.8
TOTAL	324,630	46,613	14.4	57,523	17.7	88,916	27.4

Oil Palm

Between 2017 to 2021, the oil palm industry contributed about 37% annually to the agriculture sector in Malaysia. In 2019, the total area planted with oil palm in Malaysia reached 5.9 million ha, with 46.9%, 26.2% and 26.9% of the areas been located in Peninsular Malaysia, Sabah and Sarawak respectively (Table 4.17). This has enabled Malaysia to produce 19.86 million tonnes of crude palm oil (CPO) in 2019 (Table 4.18).

Table 4.17: Oil Palm Planted Area (hectares) in Malaysia

Region	2000	2005	2010	2016	2017	2018	2019
Peninsular Malaysia	2,045,500	2,298,608	2,524,672	2,679,502	2,708,413	2,727608	2,769,003
Sarawak	330,387	543,398	919,418	1,506,769	1,555,828	1,572,477	1,586,673
Sabah	1,000,777	1,209,368	1,409,676	1,551,714	1,546,904	1,549,245	1,544,481
TOTAL	3,376,664	4,051,374	4,853,766	5,737,985	5,811,145	5,849,330	5,900,157

Source: MPOB, 2020

Table 4.18: Oil Palm Production (metric tonnes) in Malaysia

Region	2000	2005	2010	2016	2017	2018	2019
Peninsular Malaysia	7,211,539	8,291,252	9,498,120	8,886,638	10,575,920	10,197,446	10,583,788
Sarawak	520,236	1,336,638	2,179,601	3,585,286	4,128,066	4,179,339	4,237,411
Sabah	3,110,320	5,333,764	5,315,996	4,847,253	5,215,345	5,139,356	5,037,168
TOTAL	10,842,095	14,961,654	16,993,717	17,319,177	19,919,331	19,516,141	19,858,367

Source: MPOB, 2020

Climate variabilities such as *El Niño* and *La Niña* affect the physiological processes at the early growth stages of the palm. These subsequently have a significant impact on the yield. This was proven by the low CPO production per hectare in 2016, which was due to the prolonged dry spell by the 2014-2016 *El Niño* episode. On the other hand, in the past, the *La Niña* had caused severe flooding in some low-lying oil palm areas. Although oil palm is a robust crop under extreme conditions, however, most of oil palm growth and productivity could be affected if exposed to prolonged total submergence. The 2010-2011 floods had affected the harvesting and collecting activities in these areas, and had caused losses of fresh fruit bunch (FFB).

Floods

The total oil palm plantation area prone to floods in the country was projected to increase by 1.45%, from the assessed baseline timeline (1971-2000) affected areas of 166,873 ha (6.03%) to 207,001 ha (7.48%) up to 2100 (Table 4.19). The most vulnerable planted areas up to 2100 are located in Perak (81,817 ha), Johor (50,390 ha), Pahang (37,622 ha) and Selangor (12,445 ha).

Table 4.19: Projected Flood Prone Oil Palm Planted Areas at Baseline Timeline (1971-2000) and up to 2100 in Peninsular Malaysia

State	Planted Area In 2019 (ha)	Projected flood prone oil palm planted areas (ha)			
		Baseline timeline (1971-2000)	%	Up to 2100	%
Johor	758,535	41,568	5.48	50,390	6.64
Kedah	90,721	4,971	5.48	6,054	6.67
Kelantan	171,345	4,645	2.71	5,631	3.29
Melaka	57,340	1,163	2.03	1,475	2.57

State	Planted Area In 2019 (ha)	Projected flood prone oil palm planted areas (ha)			
		Baseline timeline (1971-2000)	%	Up to 2100	%
Negeri Sembilan	**188,979**	**3,641**	**1.93**	**4,350**	**2.30**
Pahang	**768,397**	**28,027**	**3.65**	**37,622**	**4.90**
Perak	**407,603**	**67,326**	**16.52**	**81,817**	**20.07**
Pulau Pinang	**13,800**	**357**	**2.59**	**654**	**4.74**
Selangor	**130,671**	**9,981**	**7.64**	**12,445**	**9.52**
Terengganu	**180,721**	**5,195**	**2.87**	**6,564**	**3.63**
Perlis	**891**	**Not assessed**	**Not assessed**	**Not assessed**	**Not assessed**
TOTAL	**2,769,003**	**166,873**	**6.03**	**207,001**	**7.48**

Dry Spells

Future vulnerability and impact assessment had been carried out for the oil palm planted areas in the four main growing states in Peninsular Malaysia. The assessment showed that the Pahang River basin and Coastal 4 region could be the most affected planted areas for the projected future period up to 2050 (Table 4.20). Among the projected dry periods for the four planted areas, extra attention should be given to the late-decades of 2030s and 2040s, as dry spells could occur simultaneously at all these four areas. Further detailed dry spell assessments carried out for oil palm planted areas in Johor (Coastal 4) and Pahang indicated the affected acreage to be 60.2% (456,868 ha out of 758,535 ha) and 20.5% (157,410 ha out of 768,397) of the planted areas respectively by 2050.

Table 4.20: Projected Dry Periods (by decades) at the Four Main Oil Palm Planted Areas by 2050

River Basin / region	Projected dry periods by decades			
	Decades	By early-decade	By mid-decade	By late-decade
Pahang	**2020s**		✓	✓
	2030s			✓
	2040s		✓	✓
Coastal 4	**2020s**			✓
	2030s			✓

River Basin / region	Projected dry periods by decades			
	Decades	By early-decade	By mid-decade	By late-decade
	2040s	✓	✓	✓
Muar	2020s			
	2030s			✓
	2040s	✓		✓
Perak	2020s			✓
	2030s	✓		✓
	2040s			✓

Sea Level Rise

Assessment to potential coastal inundation of oil palm planted areas was carried out for areas along the coastlines of Peninsular Malaysia. The total oil palm plantation area in the country prone to SLR was projected to increase to 144,368 ha and 194,506 ha by 2050 and 2100, respectively, from the projected current timeline (2022) prone area of 71,342 ha (Table 4.21). The most vulnerable planted areas are located in Selangor with total vulnerable areas of 62,627 ha and 78,547 ha by 2050 and 2100, respectively. This is followed by Penang, Perak and Johor.

Table 4.21: Projected Oil Palm Planted Areas Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State	Projected oil palm planted areas affected by SLR (ha)					
	Current timeline (2022)	%	2050	%	2100	%
Johor	41,236	5.44	45,799	6.04	58,907	7.77
Kedah	34	0.04	231	0.25	312	0.34
Kelantan	39	0.02	66	0.04	114	0.07
Melaka	541	0.94	689	1.20	1,231	2.15
Negeri Sembilan	574	0.30	803	0.42	1,549	0.82
Pahang	31	0.00	55	0.01	499	0.06
Perak	22,826	5.60	27,947	6.86	43,839	10.76
Pulau Pinang	2,703	19.59	3,133	22.70	4,438	32.16
Selangor	877	0.67	62,627	47.93	78,547	60.11
Terengganu	2,480	1.37	3,019	1.67	5,071	2.81
Perlis	0	0	0	0	0	0
TOTAL	71,342	2.58	144,368	5.21	194,506	7.02

Rubber

In 2019, there were 1.132 million hectares of rubber planted areas in Malaysia, of which around 68.6% was located in Peninsular Malaysia (Table 4.22). The balance was located in Sabah and Sarawak. These planted areas produced 639,830 metric tonnes of natural rubber production (Table 4.23). Smallholders make up of about 90% of the total rubber planters in the country.

Table 4.22: Rubber Planted Area (hectares) in Malaysia

Region	2000	2005	2010	2016	2017	2018	2019
Peninsular Malaysia	1,184,950	1,048,980	772,650	770,530	766,680	766,900	776,737
Sarawak & Sabah	245,730	221,000	247,730	307,460	315,020	318,090	355,168
TOTAL	1,430,680	1,269,980	1,020,380	1,077,990	1,081,700	1,127,020	1,131,905

Source: MRB Pocket Book 2022

Table 4.23: Rubber Production (metric tonnes) in Malaysia

Region	2000	2005	2010	2016	2017	2018	2019
Peninsular Malaysia	902,589	1,057,111	864,927	638,498	687,957	564,394	593,597
Sarawak & Sabah	25,019	68,912	74,314	52,181	52,181	38,935	46,234
TOTAL	927,608	1,126,023	939,241	673,513	740,138	603,329	639,830

Source: Department of Statistics Malaysia

Floods

According to the flood risk assessment conducted for Peninsular Malaysia, the projected planted areas prone to floods showed an increment from the baseline timeline (1971-2000) of 33,093 ha to 39,205 ha up to 2100 (Table 4.24). The planted areas in Perak could be the most affected with 11,674 ha and 13,717 ha at baseline timeline (1971-2000) and up to 2100, respectively. This is followed by Kelantan (from 9,422 ha to 10,940 ha) and Pahang (from 5,180 ha to 6,192 ha). Flood depths of more than 3 m were identified for the affected planted areas in these two states up to 2100.

Table 4.24: Projected Flood Prone Rubber Planted Area and Average Flood Depth at Baseline Timeline (1971-2000) and Up To 2100 in Peninsular Malaysia

State	Baseline timeline (1971-2000)		Up to 2100	
	Projected Affected Area (Ha)	Projected Ave. Flood Depth (m)	Projected Affected Area (Ha)	Projected Ave. Flood Depth (m)
Johor	1,485	1.7	1,854	1.9
Kedah	2,326	2.0	2,779	2.3
Kelantan	9,422	3.2	10,940	3.6
Melaka	125	1.5	160	1.8
Negeri Sembilan	529	1.7	689	2.0
Pahang	5,180	2.6	6,192	3.1
Perak	11,674	2.5	13,717	2.9
Perlis	0	0	0	0
Pulau Pinang	107	2.8	127	2.1
Selangor	373	1.6	452	2.0
Terengganu	1,871	1.6	2,296	1.9
TOTAL	33,093	-	39,205	-

Extreme Wet

Risk assessment to potential floods due to projected extreme wet weather by 2050 was also carried out at the Kedah, Coastal 12, Muar, Pahang and Kelantan rubber growing regions, which account for 58.2% of the rubber cultivated areas in the country. The planted areas in Pahang were among the most affected areas (Table 4.25). Among the projected extreme wet periods of the five planted areas, extra attention ought to be given to the early-decade of 2040s, as it is the projected extreme wet period at all of these five areas. The planted areas in Pahang and Kelantan seem to be vulnerable in 2030s.

Table 4.25: Projected Extreme Wet Weather (by decades) at the Five Main Rubber Planted Areas by 2050

River Basin / Region	Projected extreme wet periods by decades			
	Decades	By early-decade	By mid-decade	By late-decade
Kedah	2020s			✓
	2030s			
	2040s	✓		
Coastal 12	2020s			✓
	2030s		✓	
	2040s	✓		
Muar	2020s			
	2030s	✓		
	2040s	✓		✓
Kelantan	2020s			
	2030s	✓	✓	✓
	2040s	✓		
Pahang	2020s	✓	✓	
	2030s	✓	✓	✓
	2040s	✓		✓

Dry Spells

Risk assessment to potential future dry spells was carried out at Kedah, Coastal 12, Perak, Muar, Pahang and Kelantan areas in Peninsular Malaysia for the period up to 2050 (Table 4.26). These areas account for 72.8% of the rubber cultivated areas. Among the projected dry periods of the six planted areas, extra attention ought to be given to the late-decades of 2030s and 2040s, as these are the projected dry periods at majority of these six areas.

Table 4.26: Projected Dry Periods (by decades) at the Six Main Rubber Planted Areas by 2050

River Basin / region	Projected dry periods by decades			
	Decades	By early-decade	By mid-decade	By late-decade
Kedah	2020s		✓	
	2030s	✓		
	2040s	✓		✓
Coastal 12	2020s		✓	
	2030s	✓		✓

River Basin / region	Projected dry periods by decades			
	Decades	By early-decade	By mid-decade	By late-decade
	2040s			✓
Kelantan	2020s		✓	✓
	2030s			
	2040s			
Pahang	2020s			✓
	2030s			✓
	2040s		✓	
Perak	2020s			✓
	2030s	✓		✓
	2040s			✓
Muar	2020s			
	2030s			✓
	2040s			✓

Sea Level Rise

The rubber planted areas prone to SLR were projected to increase from 664 ha at the current timeline (2022) to 1,056 ha by 2050 and 2,346 ha by 2100 (Table 4.27). The significant increase in inundated rubber planted areas by 2100 is mainly from Perak (from the current timeline of 306 ha to 1,241 ha). Increments could also occur in Johor, Melaka, Selangor and Terengganu.

Table 4.27: Projected Rubber Planted Areas Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State	Projected rubber planted areas affected by SLR (ha)		
	Current timeline (2022)	2050	2100
Johor	44	48	103
Kedah	5	7	12
Kelantan	2	6	18
Melaka	143	170	286
Negeri Sembilan	26	54	92
Pahang	0	0	0
Perak	306	570	1,241
Perlis	0	0	0
Pulau Pinang	0	0	0
Selangor	1	1	72

State	Projected rubber planted areas affected by SLR (ha)		
	Current timeline (2022)	2050	2100
Terengganu	**137**	**201**	**521**
TOTAL	**664**	**1,056**	**2,346**

Cocoa

In Malaysia, cocoa is the third most important commodity crop after oil palm and rubber. In 2019, the total acreage of cocoa cultivation was 5,868 ha with a production of 1,017 metric tonnes dry cocoa beans.

The required annual rainfall for optimum cocoa yield is about 1250 to 3000 mm with dry season not exceeding three consecutive months (rainfall not less than 100 mm per month). Minimum temperature required for cocoa cultivation is between 19 to 21 °C, while maximum temperature is between 30 to 32 °C. Optimum relative humidity of cocoa cultivation ranges within 85 to 90% with the average sunshine hours from 5.0 to 5.5 hours per day. Initial research findings showed that temperatures higher than 36^{o}C affected cocoa pod production. This observation was recorded at the Cocoa Research and Development Centre (CRDC) in Jengka Pahang where recorded temperature of 37-39^{o}C in January 2018, and more than 36^{o}C from March to May 2018, resulted in no pods production. A similar pattern was observed in 2019. However, long term observation is required to assess the impact of climate change on cocoa production.

Livestock

The Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) has projected Malaysia's cattle population to increase by 15% and 19% and the total poultry to increase by 8% and 11%, by 2030 and 2050 respectively, from the 2016 baseline. Under the National Agrofood Policy 2021-2030 (NAP 2.0), the government has targeted a self-sufficiency level target of 50% for beef and 100% for fresh milk by 2025.

In general, livestock health is affected by climate change especially through extreme weather events. General impacts observed during flooding seasons are the destruction of farms and loss of livestock. More intense rainfall led to the emerging of water-related diseases, with more worm infection incidence. Climate change also affects food supply for livestock, for example poor pasture growth due to prolonged dry spells. In addition, prolonged dry spell also affects the production, fertility and longevity of the animals.

The effects of heat stress on livestock and poultry are the reductions of productivity and reproductive efficiency. Increased temperature and humidity can lead to faster development of disease-causing parasites and pathogens, both directly and/or indirectly. Climate change can also influence disease transmission by altering the ecosystem structure and function when global mean temperatures increase and exceed 2-3^{o}C.

Livestock can be raised within the local diurnal temperatures fluctuating between 23°C to 34°C and relative humidity between 55% to 98%. Local simulation studies on the impact of temperature and humidity change utilising enclosed housing systems with environmental control had concluded that the reduction in temperature increases the milk yield in dairy production, while a study on local environment indicated that the average daily gain (ADG) and feed conversion ratio (FCR) in beef cattle breed were found to be better within a cooler environment.

Under extreme conditions, when Temperature-Humidity-Index (THI) reaches 93 (for example maximum temperature reaching 35-37°C and relative humidity is at around 80%), severe heat stress would be induced thus affecting milk production of dairy cattle. Mortality will occur when THI exceeds 100 (temperature exceeds 40°C and relative humidity reaches 80%).

Fisheries and Aquaculture

In 2019, the fishery sector contributed approximately 12% of the agriculture sector's contribution to the national Gross Domestic Product (0.9% of GDP) with an annual growth rate of 0.04%. The Per Capita Consumption (PCC) was recorded at 45.51 kg per person per year with a Self Sufficiency Level (SSL) of 93%. A production of 1.87 million metric tonnes of food fish, 287.5 million pieces of ornamental fish, and 51.7 million bundles of aquatic plants, with a total value of RM15.26 billion, were reported in 2019.

Floods

The projected current flood prone freshwater culture system areas are not expected to show any significant increment up to 2100, except for the freshwater culture ponds located in Johor and Perak, and the ex-mining ponds located in Perak. The current flood prone brackish water culture system areas did not show any change in the projection up to 2100.

Dry Spells

Prolonged dry spells of up to two consecutive months coupled with more than 50% of rainfall reduction were projected to occur in some particular years at Kelantan River basin, Pahang River basin, Linggi River basin and Muar River basin by 2050. The sudden drop of water level in rivers and lakes due to prolonged dry spells would impact the overall production of cultured fish. This would lead to unhealthy water quality that could predispose disease infection.

Surface Temperature

Increase in sea surface temperature may cause migration and extinction of vulnerable aquatic species and changes in aquatic biodiversity due to more frequent occurrence of algal blooming, damage to coral reefs and physiological changes in aquatic. Concurrently, increase in inland temperatures may also bring changes to the limnological stratification and reduce primary productivity and fish food supply.

Sea Level Rise

One of the impacts of SLR and consequential coastal inundation will be damages to fishing infrastructures and aquaculture areas, including loss of mangrove swamps and shellfish farming areas. Extreme water salinity due to inland salt water intrusion induces stress on the pond's ecosystem and thus reduce freshwater aquaculture. Changes in ocean currents and higher seawater level due to global warming will bring changes in coral reefs and mangroves area, which will reduce marine (capture fish) and aquaculture productions.

Under the future scenario, the current freshwater culture ponds and ex-mining pools in Perak are projected to be vulnerable to SLR by 2050. However, no further significant increment of SLR prone areas is expected in this state by 2100. The culture ponds in Johor, Kedah and Selangor were projected to have higher risk exposure to SLR by 2100.

Among the brackishwater culture systems, hatcheries and ponds were projected more prone to SLR by 2050 and 2100. Hatcheries in Terengganu show an increasing trend in their flood prone areas throughout the century. The increment of SLR prone pond areas by 2100 are mainly at the ponds in Negeri Sembilan, Sabah and Sarawak.

4.6.2 Adaptation Measures

The National Agricommodity Policy (DAKN) 2021-2030, which was launched in 2022, is a continuation of the National Commodity Policy (DKN) 2011-2020. It is part of the Malaysian's Government efforts to drive the development of the agri-commodity sector in a more sustainable, competitive and market-oriented manner. The DAKN 2021-2030 will be used as a reference for the country's commodity industry in terms of environment, social and governance (ESG) as well as towards achieving the Sustainable Development Goals 2030 (SDG 2030). Meanwhile, The Malaysia's National Agrofood Policy 2021-2030 (NAP 2.0) has been formulated with the vision of developing a sustainable, resilient, and technology-based agro-food sector in driving economic growth, improving people's well-being as well as prioritising food security and nutrition, in line with the global goals as aspired in Sustainable Development Goals 2030 (SDG 2030).

Rice

Adaptation measures for a cropping system requires proper planning. Several measures have been taken to improve water resources for irrigation in the granary areas during dry seasons, and proper field drainage during the wetter seasons. These measures include scheduled release of water from dams, re-use of drainage water using water pumps, mobilization of water pumps, water monitoring using telemetry systems and cloud seeding.

In KADA, three additional screw water pumps have been installed to cater for sufficient irrigation water supply during dry spell conditions. In the event of excess water from rain, proper drainage channels can be designed to divert water from the areas. In tandem, the development of the submergence-tolerant rice varieties is also being conducted by MARDI in collaboration with the Food and Agriculture Organization (FAO).

In 2019, a pilot study on a new water management technique that helps to improve water use efficiency in irrigated fields through the modified alternate wetting and drying technique was carried out in Kampung Selarong, Kedah. The technique helps to save up to 35% of water usage in rice production system without affecting the yield (Aziz et al., 2020).

The identification of the Malaysian rice germplasm with drought, salinity and submergence tolerance that provide a high yield potential under extreme weather conditions is being conducted by MARDI. The development of a new drought-tolerant rice variety that carries drought-tolerant QTL (*qDTY*s) genes is currently being undertaken. The new variety with integrated drought-tolerant genes is expected to produce high-yielding grain similar to the MARDI Siraj 297. The development of the salinity-resistant rice varieties as adaptation measure for saltwater intrusion by MARDI is still at an early stage. Screening of the most advanced potential varieties below salinity stress is being implemented.

Livestock

Climate change impact to livestock was first loosely addressed by the Malaysia's Livestock Breeding Policies (2013). The National Agrofood Policy 2021-2030 (NAP 2.0) has outlined strategies to enhance genetic value of livestock through the application of scientific knowledge and technology, towards moving up the value chain in sustainable animal production in this changing climate.

Indigenous breeds such as the Kedah-Kelantan cattle, Brahman and Katjang goat were identified for better adaptation towards heat stress and tropical diseases. The Katjang goat through crossbreeding with the Boer goat, had resulted in the Boer-Katjang goat with its higher growth performance.

In 2021, several projects were undertaken to improve local dairy productivity with both imported and locally available dairy cattle breed. The imported breed includes the Jersey-Friesian cattle from Australia. Another dairy cattle breed, the Mafriwal, developed by crossbreeding of Sahiwal and Friesian breeds is. This breed is expected to increase its milk production and population under a National Dairy Plan (2021-2025). Other programmes developed to increase the productivity include the development of SOP for fertility improvement of dairy goats, feed formulation for optimum milk yield production, as well as economic analysis for dairy goat production. MARDI has introduced a local chicken breed known as the Ayam Saga to meet the demand for chicken meat and egg supply. Local research institutions are moving towards this aspect especially in evaluating locally available breeds that are heat and disease tolerant.

Fisheries and Aquaculture

A program called myKomuniti Perikanan (myKP) is being implemented by the Department of Fishery (DoF) Malaysia to help the marine and inland fishermen with various activities in the fisheries value chains. The program also acts as the platform to communicate about risks related to climate change. Some other measures such as Fishing Site Identification (FSI) system and conservation of fishing zones continue to be implemented. Broodstock development programs and species prioritisation for aquaculture are also being implemented to produce new breeds in order to increase the fish production.

The aquacultural production areas that are potentially affected by rising sea surface temperature and SLR in the not-too-distant future are being identified using the *geographic information system* (GIS) initiatives. Aquaculture producers are also encouraged to adopt the latest technologies such as indoor and controlled farming, the Recirculation Aquaculture System (RAS), the Integrated Multi-trophic Aquaculture (IMTA) and the use of Internet of Things (IoT) to optimize production in the face of climate changes.

Oil Palm

The Revised Malaysian Sustainable Palm Oil (MSPO) Standards is the current initiative by the government to promote sustainability in the palm oil industry. Climate change elements are also included in this Standard. This includes water management system, which depends on the soil type and topographic condition. Information on pest and disease had also been extended through *The SawitSecure* apps.

More research on impact of climate change to the oil palm crop productivity and diseases, such as the adoption of Ganoderma disease resistant palms, had been initiated by MPOB. Crop Model simulations to study the impact of climate change on oil palm productivity have also been carried out regularly. Additionally, research to identify and producing new planting materials with high Water Use Efficiency (WUE) traits, drought and floods resistance, and other desirable important attributes that make them resilient to climate change as well as being suited to different agro-ecological regions, have also been initiated by the MPOB.

Rubber

A breeding and selection programme to develop clones with climate-resistant traits (yield and growth performance), that is concurrently resistant to *Pestalotiopsis* leaf fall disease and environmental stresses such as drought and flooding, has been initiated by The Malaysian Rubber Board (MRB). A gravimetric phenotyping system to screen and evaluate the developed drought tolerant clones by MRB is at the development stage. The evaluation is based on the phenotypic and water use efficiency (WUE) variation of the rubber clone in dry soils.

In line with technological advancement, a geospatial system that integrates databases for planted rubber regions, soil type, planted clones, rubber disease distribution, and agro-climatic conditions, is utilised to identify the planting areas favourable for rubber. An integration of simulation models known as the RRIM EcoSmart System, is being used to forecast the effects of climate change on rubber cropping regions.

Cocoa

A study on the identification of drought and flood tolerant cocoa clones commenced in late 2015 is still ongoing. Initial assessment on 24 commercial cocoa clones showed that most of the clones have tolerant traits against flood and drought conditions.

Adaptation of cocoa to extreme dry weather using fertigation systems was initiated in 2018. Drip fertigation systems were installed at the CRDC Bagan Datuk Perak and at the CRDC Jengka Pahang, to assess the efficiency of field fertigation in increasing cocoa productivity, regardless of long drought period. It was found that the higher amount of fertilizers applied, the higher pod count was recorded. The efficiency of the system is being assessed continuously, and data has been collected since 2018.

Stress tolerance of cocoa trees subjected to smart water gel was investigated on the 6 months old hybrid cocoa trees. The study found that cocoa trees protected with shade and water gel had better growth, and higher chlorophyll content, leaf area and more green leaves. Thus, smart water gel can be introduced to the farmers during transplanting, especially during the dry and hot weather periods, to achieve a higher survival rate after planting.

4.7 Forestry and Biodiversity

4.7.1 Impact and Vulnerability

Forestry

There were 18.135 million hectares of forest areas (54.9% of the total land area) in Malaysia in 2019. The forest is generally divided into three categories according to the degree of protection and land use classification, namely; (i) Permanent Reserved Forest / Forest Reserved / Permanent Forest Estate (10.684 million ha), (ii) Protected Areas / Totally Protected Areas (3.360 million ha), and (iii) State Land Forest (4.091 million ha).

Permanent Reserved Forest is managed sustainably following Malaysia’s criteria and indicators for sustainable forest management for natural forest and plantation forest. In considering climate change impact on the forest ecosystems of the Permanent Reserved Forest, three forest types namely; (a) the Inland Forests (9.682 million ha), (b) Peat Swamp Forests (0.417 million ha) and, (c) Mangrove Forests (0.334 million ha), were assessed in this report.

Dry Spells

Forest fires are exacerbated by climate change. In Malaysia, forest fire incidences increased during prolonged dry periods. Peatland is predisposed to forest fire due to the drying of the peat, although it may also occur in the inland forest. Usually fires from surrounding degraded area would spread into the forest. The potential for higher incidences of forest fire occurrence was assessed based on the likelihood of projected prolonged dry spells lasting at least four months or more.

A total of 58 peat swamp forest reserves (20 in Peninsular Malaysia, 25 in Sabah and 13 in Sarawak) was assessed for their vulnerabilities to such prolonged dry spells. The assessments showed that extra attention needs to be given to the peat swamp forest reserves in Peninsular Malaysia in the mid-century and late-century (Table 4.28). In Sabah, extra caution needs to be taken in the early-century, specifically in the Kulamba Wildlife and Kulamba Wildlife Reserve (Extension) where seven consecutive extreme dry months was projected. In Sarawak, the similar situation was projected for early-century and mid-century

Table 4.28: Projected Dry Periods in Peat Swamp Forest by 2100

Location	Projected dry spells by 2100		
	By early-century	By mid-century	By late-century
Peninsular Malaysia		✓	✓
Sabah	✓		
Sarawak	✓	✓	

Sea Level Rise

The impact of SLR on mangrove forest, inland forest and peat swamp forest have been assessed for the coastlines and coastal areas of Malaysia. Under the future scenario, an area of 40,749 ha of mangrove forest reserves in Peninsular Malaysia were projected to be affected by 2050 (Table 4.29). There were 283 ha of peat swamp forest and 1,283 ha of inland forest reserve areas projected to face the similar situation by the same timeline.

Table 4.29: Projected Forest Areas Affected by SLR at Current Timeline (2022), 2050 and 2100

Location	Forest type	Projected forest areas affected by SLR (ha)		
		Current timeline (2022)	2050	2100
Peninsular Malaysia	**Mangrove forest**	**38,112**	**40,749**	**47,913**
	Peat swamp forest	**215**	**283**	**563**
	Inland forest	**1,154**	**1,283**	**1,763**
Sabah	**Mangrove forest**	**159,165**	**200,919**	**226,589**
	Peat swamp forest	**752**	**901**	**1,982**

Location	Forest type	Projected forest areas affected by SLR (ha)		
		Current timeline (2022)	2050	2100
	Inland forest	**59,489**	**61,015**	**72,154**
Sarawak	**Mangrove***	**12,930**	**16,679**	**34,725**
	Peat swamp forest	**2,416**	**5,974**	**19,696**
	Inland forest	**526**	**1,034**	**3,736**

* The assessment was carried out for the permanent forest estate, totally protected areas, state land and agricultural land.

Mangrove forest could become more vulnerable with 47,913 ha estimated being affected by 2100 (Table 4.29). The affected mangrove forests were projected to be in Perak (25,863 ha), Johor (10,993 ha), Selangor (6,732 ha), Kedah (3,564 ha), Pahang (261 ha), Pulau Pinang (258 ha), Terengganu (94 ha), Melaka (84 ha) and Negeri Sembilan (63 ha). By 2100, the affected inland forest was projected to be in Kedah (993 ha), Perak (688 ha), Terengganu (65 ha), Perlis (16 ha) and Melaka (0.6 ha), with a total of 1,763 ha. A total of 563 ha of peat swamp forest could be inundated in Pahang (211 ha), Selangor (69 ha), Johor (79 ha) and Terengganu (204 ha).

In Sabah, a total mangrove forest reserve of 200,919 ha was projected to be affected by 2050 (Table 4.29). About 901 ha of peat swamp forest and 61,015 ha of inland forest reserve areas were projected to face the similar problem under the same timeline. All types of forest in Sabah could be more vulnerable by 2100 with 226,589 ha of mangrove forest, 1,982 ha of peat swamp forest and 72,154 ha of inland forest were projected to be affected by SLR.

In Sarawak, a total of 16,679 ha mangrove forest, 5,974 ha of peat swamps and 1,034 ha of secondary forests were projected to be affected by SLR inundation by 2050. By 2100, the affected mangrove forest of 34,725 ha could be double that of 2050, while the affected peat swamp forest and secondary forest of 19,696 ha and 3,736 ha, respectively, could amount to triple that of 2050.

Biodiversity

Malaysia is one of the megadiverse countries, where most of biodiversity is found in the forest and marine ecosystems. Details of the Malaysian biodiversity information are available in the 6th National Report of Malaysia to the Convention on Biodiversity.

The direct impact of climate change on biodiversity and the ecosystem health is still unclear. Long term ecological plots at the Pasoh and Lambir Forest Reserves have yet to demonstrate species displacement due to climate change. However, one well documented example is the migration of various species of moths native to Mount Kinabalu uphill, exactly as would be expected if they are following temperature zones that are also migrating uphill as a consequence of global warming.

In addition, fragmentation of the forest results in the loss of ecological connectivity, which affects animal and plant populations, and overtime this could lead to increased vulnerability to climate change. Many forest birds, especially those that inhabit the understorey, do not readily fly over into open areas. Many fish and other aquatic species cannot survive in rivers that flow through degraded areas. Thus, many animals are trapped in areas that are too small to provide the necessary resources for their survival. Even if they do survive, over the longer term, they face genetic isolation that causes extinctions of local populations. This also applies to plants in as much as plants “move” via pollen and seed distribution.

Terrestrial Fauna

Fauna responds to climate change by migration or adaptation. The migrations usually follow an animal's preferred temperature, elevation, soil and availability of food source, while adaptation can be either genetic or phenological.

Birds

In Malaysia, birds are categorised into residential birds and migratory birds. They can be found in different ecosystems ranging from forests, inland waters, coastal and marine areas, agricultural lands, to urban, that are geographically dispersed within the three regions of Malaysia. Bako-Buntal Bay, Sarawak, is an important habitat for migratory waterbirds. This peat swamp area is recognized as a flyaway site under the East Asian-Australasian Flyaway Partnership.

Temperature is a critical climate parameter for mountain or highland birds, while freshwater is vital for the survival of stressed-out migratory waterbirds. More rainfall would create more conducive habitats for waterbirds through more wetland formations. On the other hand, prolonged dry spells would create dry forest conditions that will be vulnerable to wildfires resulting in habitat loss and food scarcity for mountain or highland birds.

Changes in bird migratory patterns due to climate change impact is difficult to establish. Extreme weather patterns usually have negative impacts on reproduction. Population crashes have been reported and linked to weather anomalies in the past. In general, adaptive capacity decreases most in vulnerable bird categories, especially the migratory birds.

Orang Utan

The primary habitat of the Orang Utan is the lowland old-growth and mosaic forest below 500m above sea level. However, lower density of Orang Utans can also be found in the higher up areas as high as 1,500m above sea level.

Climatic change and human inflicted pressures have resulted in significant reductions in the range and numbers of Orang Utan during the recent historic past. A recent analysis indicated that between 20,000 and 25,000 Orang Utan are likely to be found concentrated in small forest patches within agricultural landscapes across the island.

Elephant

In Malaysia, elephants are found in Peninsular Malaysia and in Sabah. According to the estimation by The Department of Wildlife and National Parks (DWNP) Peninsular Malaysia conducted in 2011, there were 1,223 to 1,677 Asian elephants (*Elephas maximus*) scattered in seven states, namely Kedah, Perak, Pahang, Terengganu, Kelantan, Johor, and Negeri Sembilan in Peninsular Malaysia (Salman et al., 2011). They are also distributed within the primary habitat identified as Managed Elephant Ranges (MERs) in the Belum-Temengor Forest Complex, the Taman Negara Forest Complex, and the Endau-Rompin Forest Complex (DWNP, 2013), respectively in the north, central and southern regions of the peninsular.

In Sabah, the Bornean pygmy elephants, which favour flat lands, floodplains and valleys, are found in the north-eastern part of the State. A reduction of at least 60% of population was reported in 2014 due to conversion of low-lying forests in the State to other types of land uses, primarily for agriculture. Recently, it was estimated that the remaining numbers have dwindled down to not more than 1,000 to 1,500 elephants, roaming across the state. The major MERs in Sabah include the lower reaches of the Kinabatangan River basin, Tabin and Central Sabah.

Tiger

Malaysia is one of the 13 nations where tigers still survive in the wild. According to The First National Tiger Survey conducted between 2016 and 2020 by PERHILITAN Malaysia, a total of 44,000 km^2 of the Central Forest Spine (CFS) area in Peninsular Malaysia was considered as tiger habitats, and these include all forest types from the lowland forest to the mountain forest. There are four Malayan tiger forest landscapes in the country having been recognised in the survey, which lie across the Ulu Muda-Bintang Hijau Complex, Titiwangsa Main Range, Taman Negara National Park and the Endau-Rompin Complex. The biggest threat that the Malayan tiger faces is the illegal hunting, while habitat loss is another major threat. A few years back, the Malayan tiger was infected by the Canine Distemper Virus (CDV), of which unfortunately, there is yet a medicine for cure.

Currently, there are no studies specifically looking into the impact of climate change on the Malayan tiger. However, climate change may have a substantial undeviating influence on this critically endangered terrestrial animal, and pushing them to the brink of extinction. This, definitely can be accelerated by deforestation or the unsustainable land use development that often result in bringing more severe floods and landslide affecting the habitats. Unexpected forest fires due to prolonged dry spells could also threaten their food sources.

Sambar Deer

Several studies indicated that the population of sambar deer (*Rusa unicolour*) showed a decreasing trend. One of the efforts to increase the population of sambar deer in Peninsular Malaysia is through a breeding program at the Wildlife Conservation Centre (WCC) in Perak and Kelantan.

Marine Ecosystem

Coral Reefs

Climate change is a major threat to coral loss. An increase in sea water temperatures of 1 to 2°C above the normal temperature level of 27ºC for a prolonged period would reduce coral cover through coral bleaching. Ocean warming can also indirectly kill corals through creating a more favourable sea environment for increasing the incidence and propagation of coral diseases.

The Malaysia Annual Coral Reefs Health Survey 2021 using the Reef Check Survey works in collaboration with Reef Check Malaysia showed a “fair” level (25% - 50%) of live coral cover of 44.26% on average (Figure 4.13 & Figure 4.14). This improvement could be at least partly due to the huge reduction in tourist visitors (both international and domestic) to coral reefs, specifically during the pandemic movement control operations in 2020 and 2021. However, further monitoring is required to confirm this observation which, if supported by data, may suggest that periodic site closures should be seriously considered as a management improvement recovery measure for the future.

Figure 4.13: Maps showing the reef health composition of each survey location in Peninsular Malaysia based on Live Coral Cover (Source: DOFM 2021)

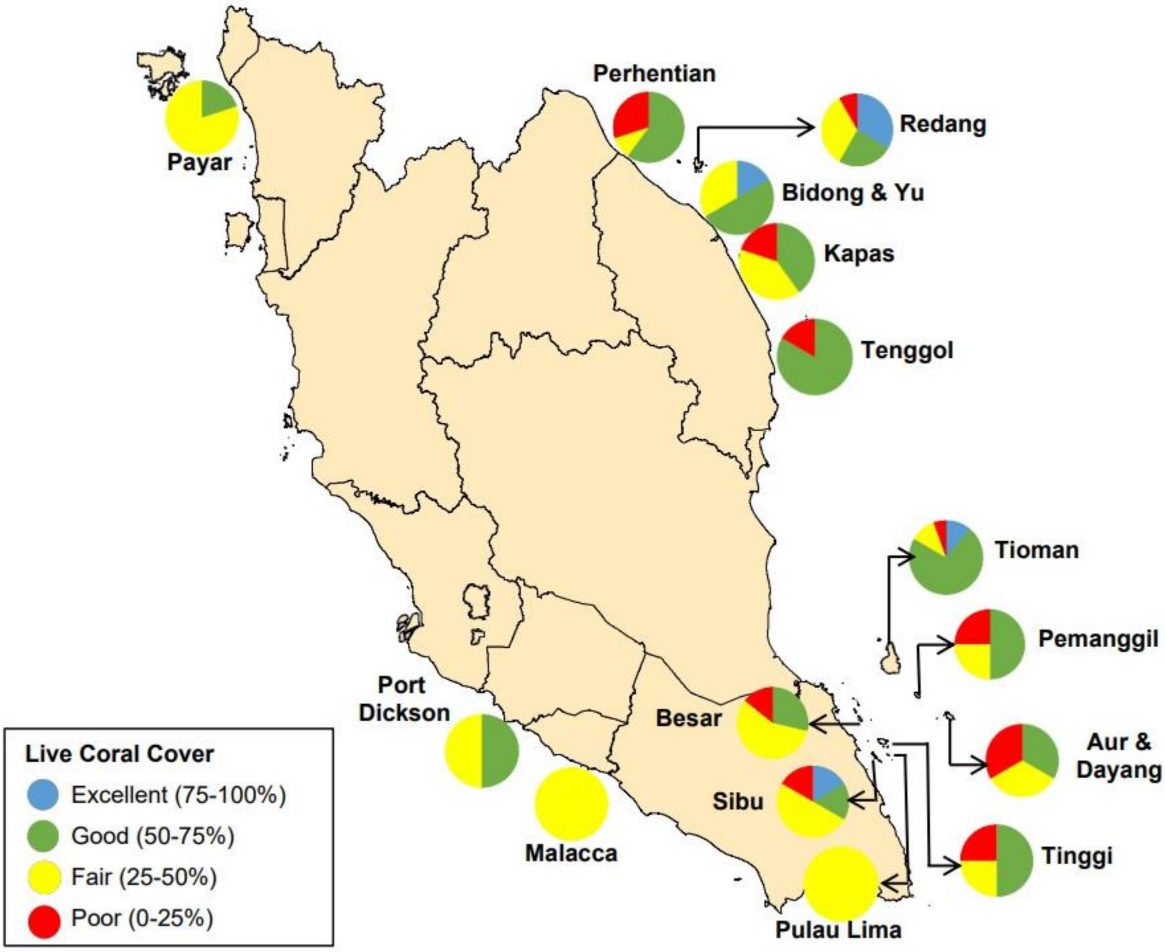
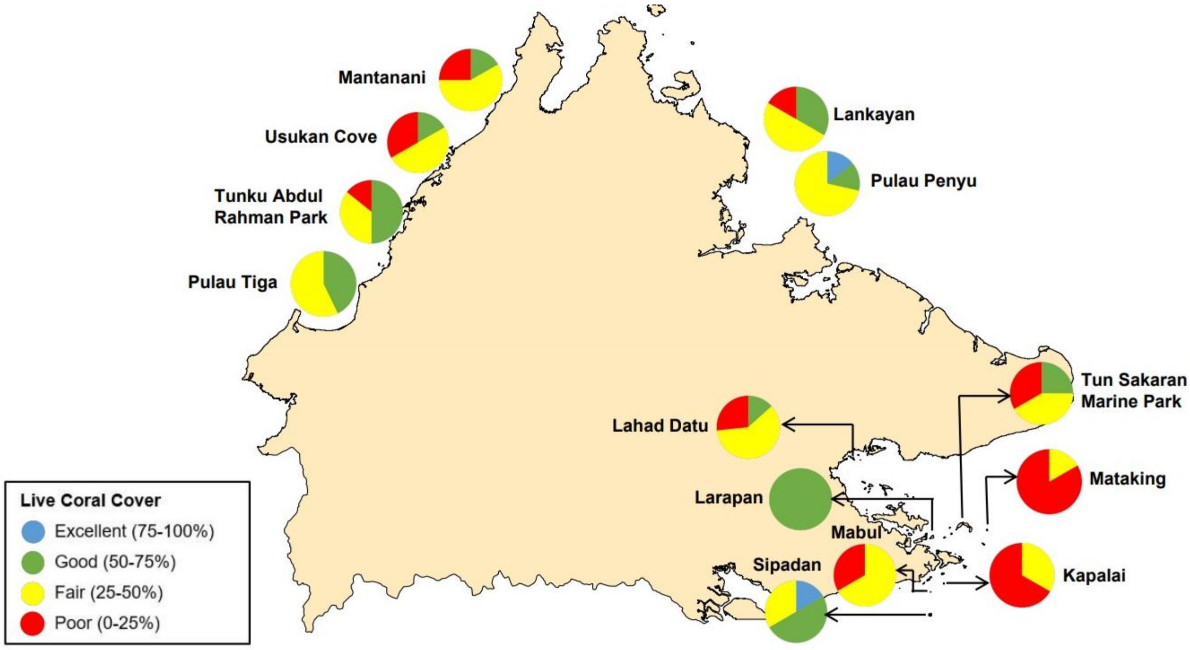


Figure 4.14: Maps showing the reef health composition of each survey location in Sabah based on Live Coral Cover (Source: DOFM 2021)



Marine Turtles

Malaysia is home to four of the extant species of marine turtles namely; the leatherback, green, hawksbill and olive ridley species. The recorded total number of turtle landings in Peninsular Malaysia from 2011 until 2020 is shown in Figure 4.15, while Table 4.30 show the nesting sites according to states.

Figure 4.15: Total number of turtle landings in Peninsular Malaysia from 2011 until 2020 (Source: Department of Fisheries Malaysia, unpublished data from FRI Rantau Abang)

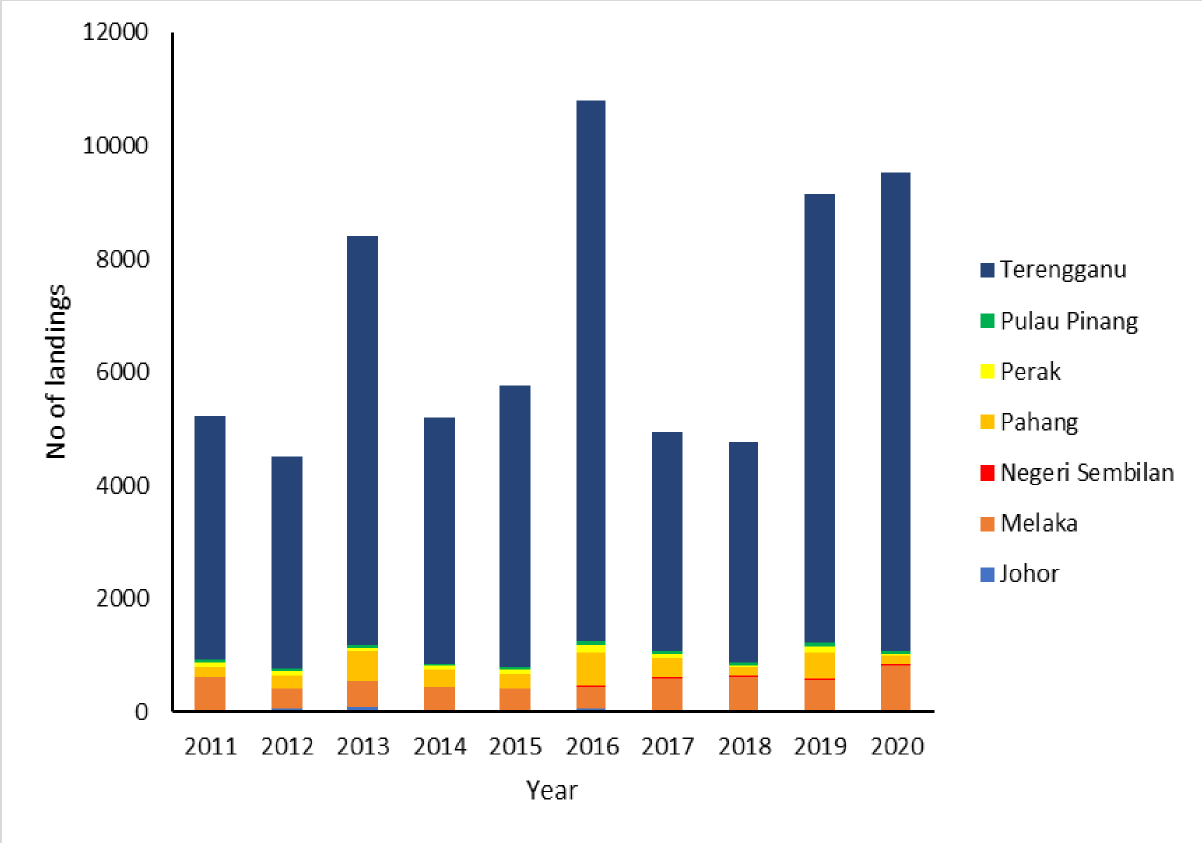


Table 4.30: Turtle Nesting Sites in Malaysia by states

State	Turtle Nesting Sites in Malaysia
Terengganu	Mak Kepit, Mak Simpan, Chagar Hutang, Pulau Pinang, Tiga Ruang, Rantau Abang, Kg. Mangkuk, Rhu Kudung, Ma' Daerah, Cakar Hutan, Geliga
Pahang	Cherating
Johor	Pulau Tinggi, Air Papan
Melaka	Padang Kemunting
Negeri Sembilan	Port Dickson
Perak	Segari
Pulau Pinang	Pantai Kerachut
Sabah	Taman Pulau Pulau Penyu (Selingan, Bakungan Kecil, Gulisan). Pulau Sipadan, Taman Laut Tun Sakaran, Kudat, Langkayan, Libaran, Pulau Maul, Pom-Pom
Sarawak	Taman Negara Talang-Satang (Pulau Talang-Talang Kecil, Pulau Talang-Talang Besar dan Pulau Satang)
WP Labuan	Pulau Rusukan Besar

In Sabah, Marine Parks including the Tunku Abdul Rahman Park, Turtle Island Park, and the Sipadan Island Park are the major nesting sites in this region. According to the Sabah Parks and Universiti Malaysia Sabah (UMS) joint studies, some of these sites, especially in the Turtle Island Park, are affected by coastal erosion. Decline of hawksbill turtles had been observed in the Turtle Island Park due to the loss of the nesting beach at Gulisaan, which had suffered severe beach erosions. Currently, these parks are being monitored by the Sabah Parks and UMS under their coastal erosion hydrodynamics studies. Researches on impact of SLR on coastal erosion and marine mammals need to be conducted and advised.

Marine Mammals

Twenty-seven species of marine mammals are confirmed to be found in the waters surrounding Malaysia (Jaaman, 2006; Ponnampalam, 2012). A study of marine mammals at Penang Island by Rajamani et al. (2018) showed that four species of dolphin and porpoise, regularly appear within the coastal waters. However, Penang Island is a rapidly growing zone of economic importance, with massive infrastructure expansion and extensive coastal zone development and reclamation already underway. Thus, it is important to establish a marine mammal management plan for these waters to ensure their survival.

In Sabah, the Tun Mustapha Park (TMP) is generally specified as being medium in exposure to the impacts of SLR and waves during typhoons and monsoons based on a climate change vulnerability assessment. However, the medium exposure impacts could be due to the geographical location of TMP in the southern part of the typhoon belt of the Philippines and the assessment sites were located in the most sheltered areas of the islands. Therefore, further researches on impact of SLR on the marine mammals at TMP need to be conducted and advised.

4.7.2 Adaptation Measures

Forestry and Biodiversity

Extreme weather could affect forest resilience in the long term. For example, the 1997–1998 El Niño drought, increased tree mortality and hence reduced the net productivity of the forests. Additionally, a study in Borneo has shown that fragmentation reduced the forest sink and turned many edge-affected forests into a carbon source. Some measures undertaken to conserve and protect the natural ecosystem are as follows:

- Two programmes, Central Forest Spine (CFS) and Heart of Borneo (HoB) are implemented to increase resilience including to climate change of natural ecosystems. One of the strategies is to establish connectivity and corridors between forests and other ecological areas. To date, a total of 37,614 ha have been gazetted as ecological corridor under the CFS. Under the HoB, corridors between Kinabalu ECOLINC, Sipitang – Ulu Padas, Ulu Segama – Malua, Danum-Maliau-Imbak and Kinabatangan Corridor of Life in Sabah are being implemented. Sarawak will develop action plans for their Mulu- Pulong Tau ecological linkage. This measure will increase the adaptive capacity of these ecosystems to climate change.

- Malaysia plans to increase land surface and inland waters as protected areas or other effective area-based conservation measures by 20%. This will also integrate the network of Community Conserved Areas (CCA) across landscapes and seascapes, and recognise these CCAs as an integral part of the nation’s protected area network.
- As part of forest management, a requirement of buffer strips for permanent streams and rivers in Inland Forest and Peat Swamp Forest of at least 5 m in width on both sides of the stream or river and felling of trees is prohibited.
- Forest plantation design and layout shall promote the protection, restoration and conservation of natural forests. Where the forest plantation is located adjacent to an environmentally sensitive area, an adequate buffer zone shall be established and maintained.

The forest fire prevention involves agencies such as the Fire and Rescue Department, Forestry Department and the Department of Environment. Relevant measures are being undertaken by these agencies to address the issue. The State Forestry Departments have developed a plan on the prevention and control of fires within the natural and plantation forests. Each state also has assigned a forestry officer to handle all matters pertaining to forest fires. Some of the adaptation measures put in place include infrastructure developed under the 11th Malaysia Plan including installation of tube wells and checked dams. For example, a monitoring tower and reservoir for providing water for use during fire outbreaks were constructed in Kuala Langat Selatan Forest Reserve, Selangor. In Sabah, monitoring of hotspots and Fire Weather Index (FWI) as well as ground-aerial surveillance had been put in place as measures for early forest fires detection. The Forestry Department’s Fire Crew will be activated when FWI rating is medium or high. Canal blocking activities are also undertaken as part of re-wetting the drained peatlands.

In addition, in 2010, the Federal Government through the Forestry Department Peninsular Malaysia has embarked on a Tree-Planting Program involving communities as part of the national agenda for addressing climate change and improving the quality of people’s lives. Furthermore, ‘The Greening Malaysia Programme’ through ‘The 100 million Tree-Planting Campaign’ has been launched in January 2021. The campaign was launched simultaneously at the states level. Under this campaign, by the end of 2025, some 100 million trees are expected to be planted throughout Malaysia. As of August 2022, a total of 37,128,111 trees have been planted in the country (Table 4.31). The replanting programme is carried out with help from Community-Based Organizations (CBO), NGOs and private sectors.

Table 4.31: Data on Trees Planted Under 'The 100 million Trees Campaign' from January 2021 to August 2022 by states

States / Federal Territories	Trees Planted
Sarawak	13,485,185
Sabah	7,947,325
Pahang	4,661,168
Kelantan	4,478,976
Perak	3,277,995
Kedah	846,838
Johor	454,497
Terengganu	444,294
Selangor	369,307
Perlis	309,125
Melaka	292,322
Negeri Sembilan	185,957
Federal Territories of Putrajaya	183,414
Federal Territories of Kuala Lumpur	102,773
Federal Territories of Labuan	56,751
Pulau Pinang	32,184
TOTAL	37, 128, 111

The implementation of protection or restoration of mangroves programme can offer increased protection of coastal areas to SLR and extreme weather events, as well as help regulate flow in watersheds. In 2005, Malaysia launched the 'Tree Planting Programme with Mangrove and Other Suitable Species along the National Coastlines' as part of mangrove forest conservation and environmental protection activities in response to the tsunami disaster of 2004. As of 2021, through an integrated approach and involvement of all state governments, private sectors, NGOs, students and local communities, Malaysia had successfully planted 7.1 million mangrove seedlings and other suitable tree species encompassing more than 3,000 hectares of coastal area throughout the country's coastlines (Table 4.32).

Table 4.32: Data on Mangrove Planted from 2005 to 2021

Year	Planted area (Ha)	No. of trees Planted
2005	189.3	477,802
2006	113.45	539,019
2007	403.19	1,051,023
2008	620.31	1,507,120
2009	526.87	1,357,433
2010	428.86	930,995
2011	85.28	198,203
2012	52.61	54,326
2013	68.60	68,929
2014	59.3	72,428
2015	57.4	66,650
2016	106.32	163,173
2017	92.3	137,818
2018	70.2	116,541
2019	52.35	54,692
2020	56.5	70,786
2021	246.8	235,607
TOTAL	3,229.64	7,102,545

Peat fires pose a significant threat to the livelihood of local communities, as well as being a health hazard. The Forestry Department Peninsular Malaysia has taken actions to construct infrastructures to prevent forest fire especially in peat swamps. These include checked dam, tube wells, reservoir pool, watch tower, clay dyke and piezometer. In 2021, the Department of Mineral and Geoscience installed two tube wells at Kuala Langat Forest Reserve in Selangor under the Peat Fire Prevention and Monitoring Program to help in peat fires prevention. In Sabah, Forest Fire Early Detection Measures, which include monitoring hotspots and Fire Weather Index, was established as forest fire management preparedness.

Marine Ecosystem

It is targeted to have 10% of the coastal and marine territories will be conserved as marine protected areas or other effective area-based conservation measures. With this achievement, the marine ecosystem would be more resilient towards the impacts of the changing climate.

Coral Reefs

After the event of mass coral bleaching in 2010 and the ever exposed vulnerability of the marine environment due to climate change, the Department of Fisheries Malaysia started to look at ways to address the future of coral reefs through coral reef restoration. The three pillars to build the reef resilience namely water quality, herbivory and physical impacts, have to be addressed on a location-by-location basis to ensure that short-term impacts are being dealt with, and at the same time looking at building long-term reef resilience. A real-time marine park water quality monitoring system that allows real time water quality monitoring and provides a graphical format to view the historical logged data was therefore developed by the Department of Fisheries Malaysia for the building reef resilience initiative in Malaysia's water.

Marine Turtles

For Sabah's turtle conservation, Sabah Parks have increased the size of the hatchery in Sipadan Island Park, and partly shaded all the hatcheries to reduce the temperature in the hatcheries during incubation to produce a balanced sex ratio of hatchlings

Marine Mammals

In order to enhance the marine mammal habitat ecosystems, high-vulnerability sites such as in Tun Mustapha Park, Sabah, require immediate adaptation measures to protect the marine mammals living in these areas. An ecosystem-based approach to protect and restore existing coral reefs, seagrass beds and mangrove forests for example in Tiga Island is needed. Establishment of *ex situ* conservation areas as sanctuary to conserve the marine mammals would be necessary.

4.8 Cities, Built Environment and Infrastructures

4.8.1 Impact and Vulnerability

Cities

In Malaysia, a town or city is defined as one where its gazetted area together with that identified as potential development areas within its boundary, has a total population of 10,000 people or more and of which, at least 60% of its inhabitants are aged 15 years and above and, who are involved with non-agriculture activities. The rate of township development in Peninsular Malaysia had increased from 71% to 75.6% throughout the 2010-2018 period. As of 2022, it has been recognised that there are 281 towns and cities, and these are classified into five hierarchical categories, namely the global city, regional city, state city, major town and the local town.

Floods

In Peninsular Malaysia, it is quite frequent to have the typical evening high intense concentrated downpours, which tend to result in flash floods in the towns and cities at west coast; whilst, over at the east coast, monsoon floods brought by the north-east monsoon are the more common flood events, as had occurred in 2021.

Based on the hydroclimate projection and assessment, there are 86 towns and cities located over all the states of Peninsular Malaysia, except for Perlis, could be prone to floods at baseline timeline (1971-2000), and the number was projected to increase to 96 up to 2100 (Table 4.33). This includes the capital city of Kuala Lumpur for both timelines. Johor, Kelantan, Pahang, Kedah, Perak and Selangor were among the states projected to have the highest number of flood vulnerable towns and cities.

Table 4.33: Projected Number of Flood Prone Towns and Cities at Baseline Timeline (1971-2000) and up to 2100 in Peninsular Malaysia and Federal Territory of Labuan

State / Federal Territory	Projected number of flood prone towns and cities	
	Baseline timeline (1971-2000)	Up to 2100
Johor	13	14
Kedah	7	13
Kelantan	12	12
Melaka	3	3
Negeri Sembilan	3	3
Pahang	11	11
Perak	14	16
Perlis	Not assessed	Not assessed
Pulau Pinang	1	2
Selangor	18	18
Terengganu	3	3
Federal Territory (Kuala Lumpur)	1	1
Federal Territory (Putrajaya)	0	0
Federal Territory (Labuan)	0	0
TOTAL	86	96

Dry Spells

The impact due to dry spells incidents are the drying up of water supply reservoirs resulting in water supply crisis in the towns and cities. Malaysia had in previous years experienced dry spells over a number of times. The most severe drought was recorded in 1998, which in particular, had affected 1.8 million residents in southern areas of Kuala Lumpur, bringing in some periods of disrupted water supply. Some episodes of drought had happened in the country since then.

Under the future scenario, 25 towns and cities in Malaysia were projected to face extreme dry weather in the early-century (Table 4.34). They are mainly located in Melaka, followed by Johor, Sabah and Negeri Sembilan. Further into mid-century and late-century, there were 57 and 68 towns and cities, respectively, projected to face the similar situation. These include the towns and cities located in Selangor, the capital city of Kuala Lumpur and the administrative city of Putrajaya. Among the states, Melaka, Selangor and Johor could have the highest numbers of vulnerable towns and cities. There was no significant extreme dry weather projected at any town and city located in Sarawak throughout the whole century.

Table 4.34: Projected Number of Towns and Cities Affected by Dry Spells by Early-Century, Mid-Century and Late-Century in Malaysia

State / Federal Territory	Projected number of towns and cities affected by dry spells		
	By Early-century	By Mid-century	By Late-century
Johor	3	27	8
Kedah	0	0	0
Kelantan	0	0	0
Melaka	18	17	18
Negeri Sembilan	1	1	9
Pahang	0	0	0
Perak	0	0	0
Perlis	0	0	0
Pulau Pinang	0	0	0
Selangor	0	10	31
Terengganu	0	0	0
Sabah	3	1	0
Sarawak	0	0	0
Federal Territory (Kuala Lumpur)	0	1	1
Federal Territory (Putrajaya)	0	0	1
Federal Territory (Labuan)	0	0	0
TOTAL	25	57	68

Sea Level Rise

According to the SLR estimated along the Peninsular Malaysia coastlines, there were 111 towns and cities projected to be prone to SLR inundation at current timeline (2022) (Table 4.35). These towns and cities are located along the coastal areas of all the states with the majority found in Pulau Pinang, Selangor, Johor, Kedah, Melaka and Terengganu. There was no projected increase in the number of towns and cities by 2050. However, it is estimated that an additional five towns and cities could be affected by 2100.

Table 4.35: Projected Number of Towns and Cities Affected by SLR at Current Timeline (2022), 2050 And 2100 in Peninsular Malaysia and Federal Territory of Labuan

State / Federal Territory	Projected Number of Towns and Cities Affected by SLR		
	Current timeline (2022)	2050	2100
Johor	13	13	14
Kedah	11	11	11
Kelantan	9	9	9
Melaka	11	11	12
Negeri Sembilan	3	3	3
Pahang	3	3	3
Perak	9	9	9
Perlis	2	2	2
Pulau Pinang	25	25	27
Selangor	15	15	15
Terengganu	10	10	11
Federal Territory (Kuala Lumpur)	0	0	0
Federal Territory (Putrajaya)	0	0	0
Federal Territory (Labuan)	0	0	0
Total	111	111	116

Built Environment

In Malaysia, built environment lands are used for housing development, commercial development, industrial development, infrastructures and utilities, institutions and social facilities, transportation, and rest and recreational activities, along with vacant/open land for future uses. In Peninsular Malaysia, the built environment lands cover about 1,282,166.35 ha (9.71%) of the total land in the peninsular (Table 4.36).

Table 4.36: Distribution of Built Environment in Peninsular Malaysia

Land Use Types	Area	
	Ha	%
Housing	313,716	2.38
Commercial development	83,108	0.63
Industrial development	88,941	0.67

Land Use Types	Area	
	Ha	%
Infrastructures and utilities	61,288	0.46
Institutions and Social Facilities	129,531	0.98
Transportation	299,107	2.27
Rest and Recreational Purposes	49,244	0.37
Vacant land	257,232	1.95
TOTAL	1,282,166	9.71

Source: PLANMalaysia, 2021

Floods

The change in land use to accommodate the built environment has inevitably resulted in the reduction of infiltration water into the soil, which would then increase the surface water runoff leading to higher flows into drains during periods of high intensity rain and flash floods can occur. There were 75,927 ha (5.92%) of the built environmental areas in Peninsular Malaysia projected to be prone to floods at baseline timeline (1971-2000). An increment of 20,636 ha (27.18%) was projected up to 2100.

Dry Spells

Although there is no direct effect of dry spells on the built environment, prolonged dry spells tend to result in open land and forest fires, and create islands of haze overhanging the environment. Based on the projected future scenario, it is estimated that 51,373 ha or 4.01% of built environment areas in Malaysia could face dry spells in early-century. This could increase to 203,024 ha (+295.20%) by mid-century, and further increase to 229,140 ha (+346.03%) by late-century.

Sea Level Rise

At current timeline (2022), about 50,200 ha (3.92%) of built environment in Peninsular Malaysia was assessed to be affected by SLR. Under the future scenario, the affected area was projected to increase to 65,917 ha (+31.31%) by 2050 and 99,774 ha (+98.75%) by 2100.

Roads

Roads in Peninsular Malaysia are generally categorized into federal roads, state roads and expressways. In 2020, the total road length was 267,046 km, which had comprised of approximately 92.5% of state roads, 7.5% of federal roads and expressways, under the jurisdiction of Ministry of Public Works. In Sabah and Sarawak, the Pan Borneo Highway with a total length of 2,083 km is a road network on Borneo Island connecting these two Malaysian states.

Floods

Floods on roads and highways can cause public distress and asset damages in the affected areas. There were 1,111 km of roads and highways projected prone to floods, including the Pan Borneo Highway in Sabah and Sarawak, at baseline timeline (1971-2000), as shown in Table 4.37. The affected length was projected to increase to 1,325 km up to 2100. Highways in Peninsular Malaysia were projected to be more vulnerable to climate change with an additional 144 km section up to 2100.

Table 4.37: Projected Flood Prone Roads and Highways in Peninsular Malaysia and the Pan Borneo in Sabah and Sarawak at Baseline Timeline (1971-2000) and up to 2100

Type of roads	Projected Length of Flood Prone Roads and Highways (km)	
	Baseline Timeline (1971-2000)	Up to 2100
Highway	729	873
Federal Road	246	294
State Road	62	79
Pan Borneo	74	79
TOTAL	1,111	1,325

Sea Level Rise

The SLR impact assessment on the coastal roads and highways showed some 3,262 km of the roads could be prone to coastal inundation at current timeline (2022) (Table 4.38). Under future scenarios, an additional 72 km and 292 km of roads and highways are expected to be vulnerable to SLR by 2050 and 2100, respectively. State roads in Peninsular Malaysia are more vulnerable compared to highways and federal roads.

Table 4.38: Projected Coastal Roads and Highways in Peninsular Malaysia and The Pan Borneo in Sabah and Sarawak Affected by SLR at Current Timeline (2022), 2050 and 2100

Type of roads	Projected Length of Roads and Highways Affected by SLR (km)		
	Current timeline (2022)	2050	2100
Highway	603	620	640
Federal Road	1,849	1,866	1,941
State Road	778	808	915
Pan Borneo	32	40	58

Type of roads	Projected Length of Roads and Highways Affected by SLR (km)		
	Current timeline (2022)	2050	2100
TOTAL	3,262	3,334	3,554

Table 4.39 shows the breakdown of road lengths affected by SLR for the states in Peninsular Malaysia. Only highways located in Selangor showed an increment of 16.7 km (+13.1%) by 2050, while highways located in Johor showed an increment of 19.7 km (+11.5%) by 2100. For Federal Roads, roads in Johor and Pahang showed an increasing trend of being inundated throughout the century, while roads in Selangor, Negeri Sembilan, Perak and Pulau Pinang only showed increment from 2050 to 2100. State Roads were projected to be more vulnerable compared to highways and Federal Roads. The State Roads in Kedah and Pahang were projected to be affected with greater lengths of SLR inundations (more than 30 km) by 2100 as compared to the current timeline (2022) and by 2050.

Table 4.39: Projected Coastal Roads and Highways Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State	Projected Length of Roads and Highways Affected by SLR (km)								
	Highway			Federal Road			State Road		
	Current timeline (2022)	2050	2100	Current timeline (2022)	2050	2100	Current timeline (2022)	2050	2100
Johor	172.2	172.2	191.9	399.0	399.7	419.2	3.1	3.1	4.5
Kedah	62.5	62.5	62.5	158.7	158.7	158.7	153.8	153.8	186.6
Kelantan	0.0	0.0	0.0	29.5	29.5	29.5	76.1	85.1	85.1
Melaka	0.0	0.0	0.0	118.8	122.2	122.2	55.4	63.1	70.1
Negeri Sembilan	16.4	16.4	16.4	82.5	82.5	83.4	0.0	0.0	0.0
Pahang	71.9	71.9	71.9	224.8	237.7	243.7	30.3	30.3	69.2
Perak	0.0	0.0	0.0	218.5	218.5	243.5	43.8	43.8	43.8
Perlis	0.0	0.0	0.0	46.5	46.5	46.5	45.8	45.8	45.8
Pulau Pinang	128.8	128.8	128.8	131.1	131.1	133.3	61.7	61.7	78.8
Selangor	127.8	144.5	144.5	232.6	232.6	253.4	155.6	155.6	155.6
Terengganu	23.7	23.7	23.7	207.5	207.5	207.5	152.7	166.0	175.6
Federal Territory (Kuala Lumpur)	0	0	0	0	0	0	0	0	0
Federal Territory (Putrajaya)	0	0	0	0	0	0	0	0	0
TOTAL	603.2	619.9	639.7	1,849.2	1,866.3	1,940.7	778.3	808.3	915.1

Rails

The major railway lines in Peninsular Malaysia service are 1,677 km in length and consist of two major lines, one running along the entire west coast from north to south and is 1,151 km in length. The other line of length 526 km, starts at Gemas in the central point of the west coast line and head north-east ward ending at Tumpat in Kelantan. The other rail services are those inter-city lines, the KL-KLIA express rail, and the KL city metro lines. The rails are entirely electrified rail services. Currently under construction is the East Coast Railway Line.

Floods

According to Malayan Railways Limited (Keretapi Tanah Melayu Berhad, KTMB), certain sections of their route lines are prone to and are often affected by flash floods. Records of KTMB rail track affected by floods in the years 2020-2021 are summarized in Table 4.40. In December 2021, the railway tracks between the Subang Jaya and Batu Tiga KTM stations was disrupted by floods. Intercity services towards the east coast of Peninsular Malaysia are also disrupted as a result of flooding. About 300 km length of track line located on the east coast between Kuala Lipis to Tumpat is at high risks of flooding during north-east monsoon heavy rain episodes.

Table 4.40: Observed Sections of the KTMB Rail Track Affected by Major Floods in 2020-2021

Observed Affected Sections	Observed Affected Location at (km)
Kluang – Rengam	675.20 – 675.75
Pasir Gudang	29.75
Kempas Baru – Pasir Gudang	0.75 – 0.85
Kempas Baru – JB Sentral	748.75 – 749.00
Bangi – Batang Benar	433.15
Subang Jaya – Bt Tiga	18.75 – 21.02
Subang Jaya	16.10
Batang Benar – Bangi	433.20 – 444.02
Seremban	460.00
Kuala Lumpur – Bank Negara (Landasan Naik)	386.74
Batang Benar – Labu	433.42
Kawasan Stesen Serdang	404.20 – 404.70
Batu Tiga	19.65
Chegar Perah	263.00 – 263.75
Bukit Abu – Krai	423.75 – 424.00, 430.00 – 430.25
Gua Musang – Bertam Baru	337.75
Triang – Mentakab	94.50 – 95.60, 98.25 – 98.35, 122.50

Under the future projection scenario, 20 railway stations with about 183.5 km of railway section length located in Johor, Kedah, Kelantan, Pahang, Negeri Sembilan, Selangor, Pulau Pinang, Perak and Kuala Lumpur were projected to be prone to floods up to 2100 (Table 4.41). The railways and stations in Kedah, Kelantan, Pahang, Selangor and Kuala Lumpur are among the most vulnerable infrastructures to the floods.

Table 4.41: Projected Number of Flood Prone Railway Stations and Railway Section Lengths up to 2100 in Peninsular Malaysia

State / Federal Territory	Projected Number of Flood Prone Railway	Projected Flood Prone Railway Section Length (km)
Johor	0	7.0
Kedah	2	15.2
Kelantan	3	48.1
Melaka	0	0
Negeri Sembilan	0	2.5
Pahang	5	46.9
Perak	0	24.0
Perlis	Not assessed	Not assessed
Pulau Pinang	0	3.2
Selangor	6	23.4
Terengganu	0	0
Federal Territory (Kuala Lumpur)	4	13.2
Federal Territory (Putrajaya)	0	0
TOTAL	20	183.5

Sea level rise

Based on the coastal inundation assessment for the railway in Peninsular Malaysia, it has been estimated that some 297.5 km length of rail tracks located in Johor, Kedah, Pulau Pinang, Kelantan, Pahang, Perak and Selangor are currently exposed to the effects of SLR (Table 4.42). The affected length is expected to remain the same for all those states by 2050 and by 2100, except for the railway in Pulau Pinang. The affected length of railway in Pulau Pinang was projected to increase from the current timeline (2022) of 37.7 km to 38.5 km (+2.2%) by 2050 and 61.1 km (+62.1%) by 2100.

Table 4.42: Projected Coastal KTM Railway Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State / Federal Territory	Projected Railway Section Length Affected by SLR (km)		
	Current Timeline (2022)	2050	2100
Johor	42.2	42.2	42.2
Kedah	90.3	90.3	90.3
Kelantan	0.1	0.1	0.1
Melaka	0.0	0.0	0.0
Negeri Sembilan	0.0	0.0	0.0
Pahang	24.4	24.4	24.4
Perak	48.8	48.8	48.8
Perlis	0.0	0.0	0.0
Pulau Pinang	37.7	38.5	61.1
Selangor	54.0	54.0	54.0
Terengganu	0.0	0.0	0.0
Federal Territory (Kuala Lumpur)	0.0	0.0	0.0
Federal Territory (Putrajaya)	0.0	0.0	0.0
TOTAL	297.5	298.4	320.9

Ports and Jetties

In Malaysia, ports are categorized into sea port and dry/inland port. There are 28 ports established in Malaysia, which include seven national ports (Klang Port, Pulau Pinang Port, Johor Port at Pasir Gudang, Tanjung Pelepas Port, Kuantan Port, Kemaman Port and Bintulu Port) and 21 State ports (9 of the state ports are located in Peninsular Malaysia, while 4 are located in Sarawak and 8 in Sabah). There are also 35 jetties/ferry terminals to provide services for local passenger transport and vehicle transfers distributed over the states.

Dry Spells

Ships calling at ports could be affected by haze due to prolonged dry spells. There are however, no current local dry spells direct impact onto ports and jetties/ferry terminals reported. However though, lengthy dry spells that are prolonged in future may cause haze to form, and this phenomenon can disturb the operations at the ports and jetties/ferry terminals. Under the future scenario, five ports and jetties/ferry terminals were projected to be prone to dry spells by early-century, and the number is expected to increase to 12 and 13 ports and jetties/ferry terminals by mid-century and late-century, respectively (Table 4.43).

Table 4.43: Projected Number of Ports and Jetties/Ferry Terminals Affected by Dry Spells by Early-Century, Mid-Century and Late-Century in Malaysia

State / Federal Territory	Projected Number of Ports and Jetties/Ferry Terminals Affected by Dry Spells		
	By Early-Century	By Mid-Century	By Late-Century
Johor	0	7	0
Kedah	0	0	0
Kelantan	0	0	0
Melaka	3	4	4
Negeri Sembilan	0	0	2
Pahang	0	0	0
Perak	0	0	0
Perlis	0	0	0
Pulau Pinang	0	0	0
Selangor	0	0	5
Terengganu	0	0	0
Sabah	2	1	2
Sarawak	0	0	0
Federal Territory (Kuala Lumpur)	0	0	0
Federal Territory (Putrajaya)	0	0	0
Federal Territory (Labuan)	0	0	0
TOTAL	5	12	13

Sea Level Rise

There were 21 ports and jetties/ferry terminals projected to be affected by SLR at the current timeline (2022), as shown in Table 4.44. By 2050, there is expected one other additional port and jetty/ferry terminal located in Johor projected to be affected by SLR. However, by 2100, an additional 11 ports and jetties/ferry terminals, respectively located at Kelantan, Perak, Pulau Pinang, Terengganu, Sabah and Sarawak, could be affected by SLR. Sabah shows a significant increment of four ports and jetties/ferry terminals at this timeline.

Table 4.44: Projected Number of Ports and Ferry Terminals/Jetties Affected by SLR at Current Timeline (2022), 2050 and 2100 in Malaysia

State / Federal Territory	Projected Number of Ports and Ferry Terminals/Jetties Affected by SLR		
	Current timeline (2022)	2050	2100
Johor	3	4	4
Kedah	3	3	3
Kelantan	0	0	1
Melaka	0	0	0
Negeri Sembilan	0	0	0
Pahang	1	1	1
Perak	1	1	2
Perlis	1	1	1
Pulau Pinang	0	0	1
Selangor	4	4	4
Terengganu	2	2	4
Sabah	1	1	5
Sarawak	5	5	7
Federal Territory (Kuala Lumpur)	0	0	0
Federal Territory (Putrajaya)	0	0	0
Federal Territory (Labuan)	0	0	0
TOTAL	21	22	33

Airports

There are six international airports, 16 domestic airports and 18 Flight Fields (Short Take-off and Landing, STOLport) in Malaysia. Under the current situation, continuous rainfall sometimes caused slight flash floods at the arrival hall of the Penang International Airport (PIA). In Sarawak, the Lawas STOLport had previously experienced a few flood incidents in 2020-2022, with the flooded depth as high as one meter. In 2010, the Sultan Abdul Halim Airport in Kedah was closed after floodwaters seeped onto parts of the 2,745 m long runway. The operations at these airports were temporarily stopped for a few days due to the serious flooding at the runaway.

Floods

Majority of the airports in Sabah and Sarawak were projected to face flooding problems at baseline timeline (1971-2000) and up to 2100. These include five airports in Sabah and five airports in Sarawak. In Peninsular Malaysia, the airports in Perak and Kedah were projected to be flood prone at both timelines.

Dry Spells

Visibility for flights at the airports are significantly affected and flights are disrupted during the haze occurrences following prolonged dry spell periods. In Malaysia, the operations of 14 airports were reported to be disrupted during the haze phenomenon in 2015. However, the impact of the projected future local dry spells onto the infrastructures at the airport are not expected to be significant.

Under the future scenario, the airport in Melaka together with an airport in Sabah were projected to face dry spell impacts in some particular extreme dry years throughout the whole century. Similar impact was also projected for another airport in Sabah but only in the early-century and late-century. In addition, the airport in Johor was projected to be prone to dry spell in mid-century only, while an airport in Selangor was projected to be prone to dry spell in late-century only.

Sea Level Rise

The Penang International Airport was projected to face SLR inundation by 2050 and 2100. There are, however, no other airports or STOLports that were projected to be affected by SLR throughout the century.

Solid Waste Facilities

As of 2021, landfills, incinerator and transfer stations, are the means of solid waste disposal in the country. There are approximately 21 sanitary landfills, 114 non-sanitary landfills, four inert waste landfills, four incinerators and five transfer stations currently in use in the country.

Floods

Some solid waste disposal sites are vulnerable to floods. Based on the flood areal extent maps, four of the solid waste disposal sites located in Pahang, Selangor and Perak were projected to be prone to floods up to 2100.

Dry Spells

Although dry spells are expected not to seriously jeopardise the solid waste infrastructures, nevertheless, the hot seasons that are prolonged too much can become a source of fire at these waste disposal sites. There were cases where smouldering and beneath-ground fires at landfill areas started on their own during the extreme heat of the prolonged dry spells such as that at Bukit Bakri Muar Landfill and Pekan Nenas Pontian landfill in Johor in 2018, and those at Ladang Tanah Merah sanitary landfill in Negeri Sembilan in 2021, resulting in serious consequences of haze and air pollution.

Under the future scenario, prolonged extreme dry weathers were projected at some existing facilities for solid wastes located in Negeri Sembilan, Melaka, Johor, Sabah and Selangor (late-century only) in some particular years throughout the century (Table 4.45). Seven facilities from these states were projected to be prone to dry spells by early-century, and the number is expected to increase to 10 facilities each by mid-century and late-century.

Table 4.45: Projected Number of Solid Waste Disposal Sites Affected by Dry Spells in Early-Century, Mid-Century and Late-Century in Malaysia

State / Federal Territory	Projected Number of Solid Waste Disposal Sites Affected by Dry Spells		
	By Early-Century	By Mid-Century	By Late-Century
Johor	1	6	1
Kedah	0	0	0
Kelantan	0	0	0
Melaka	1	1	1
Negeri Sembilan	1	1	2
Pahang	0	0	0
Perak	0	0	0
Perlis	0	0	0
Pulau Pinang	0	0	0
Selangor	0	0	2
Terengganu	0	0	0
Sabah	4	2	4
Sarawak	0	0	0
Federal Territory (Kuala Lumpur)	0	0	0
Federal Territory (Putrajaya)	0	0	0
Federal Territory (Labuan)	0	0	0
TOTAL	7	10	10

Sea Level Rise

Five solid waste disposal sites located in Kelantan, Pulau Pinang, Perak and Selangor were projected to be affected by SLR at current timeline (2022), as well as by 2050 (Table 4.46). By 2100, four additional sites consisting of one additional site from Pulau Pinang, one site from Perlis and two sites from Terengganu, were projected to be affected by SLR.

Table 4.46: Projected Number of Solid Waste Disposal Sites Affected by SLR at Current Timeline (2022), 2050 and 2100 in Malaysia

State / Federal Territory	Projected Number of Solid Waste Disposal Sites Affected by Slr		
	Current Timeline (2022)	2050	2100
Johor	0	0	0
Kedah	0	0	0
Kelantan	1	1	1
Melaka	0	0	0
Negeri Sembilan	0	0	0
Pahang	0	0	0
Perak	1	1	1
Perlis	0	0	1
Pulau Pinang	1	1	2
Selangor	2	2	2
Terengganu	0	0	2
Sabah	0	0	0
Sarawak	0	0	0
Federal Territory (Kuala Lumpur)	0	0	0
Federal Territory (Putrajaya)	0	0	0
Federal Territory (Labuan)	0	0	0
TOTAL	5	5	9

Sewerage Facilities

As of November 2023, there are some 7,503 public sewerage treatment plants (STPs) and 1,454 network pumping stations (NPSs) facilities that are being operated and maintained by the various operators of public sewerage in Peninsular Malaysia (SPAN Water and Sewerage Factbook, 2022).

Floods

Impacts of flooding at sewerage facilities includes the overflow and shutting down of the STP and NPS. These overflows at the STP and NPS will inevitably cause deterioration to the water quality of the receiving water bodies downstream and nearby rivers. Based on the flood areal extent maps at the current timeline (1971-2000) and up to 2100, there could be 60 and 71 STPs and NPS, respectively, located in Peninsular Malaysia affected by floods (Table 4.47). There are no significant changes expected in terms of the number affected public STP and NPS at the two timelines, in most of the states. Among the states, Selangor has the highest number of affected STP and NPS at both timelines, followed by Perak, Pahang and Kuala Lumpur.

Table 4.47: Projected Number of Flood Prone STPs and NPSs at Current Timeline and up to 2100 in Peninsular Malaysia

State / Federal Territory	Total Number of STPs and NPSs Assessed	Projected Number of Flood Prone STP and NPS	
		Current Timeline (1971-2000)	Up to 2100
Johor	1,127	2	2
Kedah	693	2	2
Kelantan	50	4	4
Melaka	656	0	1
Negeri Sembilan	613	2	2
Pahang	635	5	7
Perak	1,278	10	11
Perlis	0	Not assessed	Not assessed
Pulau Pinang	684	1	2
Selangor	2,345	27	30
Terengganu	162	2	3
Federal Territory (Kuala Lumpur)	280	5	7
Federal Territory (Putrajaya)	0	Not assessed	Not assessed
TOTAL	8,523	60	71

Dry Spells

There is no immediate direct impact due to dry spell to the sewerage facilities and infrastructures. However, sewerage has always been identified as one of the river pollution sources during dry spells resulting from the less dilution in the river water. By upgrading and rationalization of old and small existing STPs and NPSs in the country, it is anticipated that the favourable discharge of treated sewage effluent into rivers on the other hand is able to increase the river flow during dry spell, with better waste water environmental disposal management.

Sea Level Rise

There are no public STPs and NPSs reported being affected by SLR. However, there may be impacts from SLR at several STP and NPS sites located nearer coastal areas, which are privately maintained that are not reported.

The projected numbers of STPs and NPSs that could be inundated due to SLR at current timeline, by 2050 and by 2100 were 402, 488 and 835 units, respectively (Table 4.48). There were no significant increments in the number of affected STPs and NPSs by 2050 projected for each state, except for Kedah, Pulau Pinang, Perak, Selangor and Johor. These five states also showed significant increments in the number of affected STPs and NPSs by 2100.

Table 4.48: Projected Number of STPs and NPSs Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State / Federal Territory	Total Number of STP and NPS Assessed	Projected Number of STP and NPS Affected by SLR		
		Current Timeline (2022)	2050	2100
Johor	1,127	47	53	82
Kedah	692	55	73	130
Kelantan	0	Not assessed	Not assessed	Not assessed
Melaka	656	9	11	26
Negeri Sembilan	643	1	1	5
Pahang	636	0	4	10
Perak	1,278	35	50	70
Perlis	73	9	10	21
Pulau Pinang	684	40	58	147
Selangor	2,345	204	226	335
Terengganu	162	2	2	9
Federal Territory (Kuala Lumpur)	0	Not assessed	Not assessed	Not assessed
Federal Territory (Putrajaya)	0	Not assessed	Not assessed	Not assessed
TOTAL	8,296	402	488	835

Water Supply Facilities

As of 2022, there are 516 water treatment plants (WTP) recorded in Malaysia, of which 329 are located in Peninsular Malaysia, 83 in Sabah, 98 in Sarawak and 6 in Labuan.

Floods

Towards the end of 2021, water supply in various parts of Selangor and Kuala Lumpur were disrupted due to the big floods that had occurred following heavy rainfall from 17 December to 19 December 2021. In Sarawak, some of the WTPs were also affected by floods at various times in 2021-2022. Based on the flood areal extent maps for the baseline timeline (1971-2000) and up to 2100, there could be 47 and 56 WTPs, respectively, prone to floods (Table 4.49). Among the states, Sarawak Johor and Pahang are expected to have the highest number of affected WTPs at both timelines. There were no significant changes in the number of affected WTPs projected for each state affected at the two timelines, except for Johor and Sarawak.

Table 4.49: Projected Number of Flood Prone WTPS at Baseline Timeline (1971-2000) and up to 2100 in Malaysia

State / Federal Territory	Total Number of WTPs Assessed	Projected Number of Flood Prone WTPs	
		Baseline Timeline (1971-2000)	Up to 2100
Johor	46	10	13
Kedah	35	1	2
Kelantan	39	5	5
Melaka	11	1	1
Negeri Sembilan	21	1	1
Pahang	73	10	11
Perak	44	6	6
Perlis	0	Not assessed	Not assessed
Pulau Pinang	9	0	0
Selangor	33	1	1
Terengganu	12	1	1
Sabah	83	0	0
Sarawak	98	11	15
Federal Territory (Kuala Lumpur)	0	Not assessed	Not assessed
Federal Territory (Putrajaya)	0	Not assessed	Not assessed
Federal Territory (Labuan)	0	Not assessed	Not assessed
TOTAL	504	47	56

Dry Spells

The effect of dry spell will not only result in the drop of water levels at the water supply dam reservoir, but also the drop in the river levels where the WTP draws its raw water for treatment. Several water treatment plants in Perlis, Perak, Johor, Pahang, Kedah and Selangor were reported to be affected by the occasional long dry spells that appeared frequently over the past few years. In Sarawak, the production of potable water at the WTP Kapit was affected in May 2022 due to low water level at the inlet point. This WTP has been experiencing this issue since 2020.

For the future scenario, there were 11 WTPs projected to possibly be affected by dry spells by early century (Table 4.50). These WTPS are located in Melaka and Sabah. Further into the mid-century and late-century, about 28 and 38 WTPs, respectively, could face similar dry spell impacts. These additional WTPs are located in Johor, Selangor and Negeri Sembilan. However, the WTP Kapit in Sarawak, which experienced dry spell impacts in the past, was not projected to face any dry spells in future.

Table 4.50: Projected Number of WTPS Affected by Dry Spells by Early-Century, Mid-Century and Late-Century in Malaysia

State / Federal Territory	Projected Number of WTPs Affected by Dry Spells		
	By Early-Century	By Mid-Century	By Late-Century
Johor	0	18	7
Kedah	0	0	0
Kelantan	0	0	0
Melaka	6	7	8
Negeri Sembilan	0	0	7
Pahang	0	0	0
Perak	0	0	0
Perlis	0	0	0
Pulau Pinang	0	0	0
Selangor	0	1	12
Terengganu	0	0	0
Sabah	5	2	4
Sarawak	0	0	0
Federal Territory (Kuala Lumpur)	0	0	0
Federal Territory (Putrajaya)	0	0	0
Federal Territory (Labuan)	0	0	0
TOTAL	11	28	38

Assessment was also carried out using the projected river flow of the WTPs. Based on the future river flow projection, it indicates that some WTPs located in Johor, Melaka, Pulau Pinang and Sabah could face lower river flow in early-century. It was also projected that those WTPs located in Pulau Pinang and Sabah could continue to face the similar problem in mid-century and late-century. Thus, alternative water sources should be planned and implemented immediately to minimise the impact on the community and environment.

Sea Level Rise

SLR shows no clear impact on the WTPs, which are usually located in the middle and upper catchment areas. However, for those WTPs located within certain distance from the river mouth or at the barrages, special precaution should be taken. According to the research carried out by NAHRIM at Sg. Rajang, Sg. Muar, Sg. Merbok and Sg. Muda, saltwater intrusion up to 2 to 11 km from the river mouth are possible if 0.7 m of SLR occurs in the late-century.

Flood Relief Centres

In Malaysia, schools, and multi-purpose and community halls, are usually used as flood relief centres. There are approximately 7,353 numbers of flood relief centres have been established in Peninsular Malaysia.

Floods

Based on the flood areal extent maps at baseline timeline (1971-2000) and up to 2100, there could be 708 (9.6%) and 910 (12.4%) flood relief centres, respectively, located in Peninsular Malaysia prone to floods (Table 4.51). Among the states, Perak and Pahang are expected to have the highest number of affected flood relief centres at both timelines, and this is followed by Selangor. Kedah showed significant increment from 43 centres at baseline timeline (1971-2000) to 131 centres up to 2100.

Table 4.51: Projected Number of Flood Relief Centres Prone to Floods at Baseline Timeline (1971-2000) and up to 2100 in Peninsular Malaysia

State / Federal Territory	Number of Flood Relief Centres Assessed	Projected Number of Flood Relief Centres Prone to Floods	
		Baseline Timeline (1971-2000)	Up to 2100
Johor	1,057	78	96
Kedah	807	43	131
Kelantan	454	55	73
Melaka	366	1	1
Negeri Sembilan	219	8	8
Pahang	883	179	191
Perak	1,057	179	214

State / Federal Territory	Number of Flood Relief Centres Assessed	Projected Number of Flood Relief Centres Prone to Floods	
		Baseline Timeline (1971-2000)	Up to 2100
Perlis	122	0	0
Pulau Pinang	379	5	13
Selangor	1,150	108	126
Terengganu	749	43	43
Federal Territory (Kuala Lumpur)	96	9	14
Federal Territory (Putrajaya)	14	0	0
TOTAL	7,353	708 (9.6%)	910 (12.4%)

4.8.2 Adaptation Measures

The phenomenon of climate change has resulted in more frequent and severe extreme weather related disasters in urban areas. In order to reduce the impact of these disasters through more effective spatial planning and land use, the PLANMalaysia has prepared the Planning Guidelines for Disaster Resilient Cities in 2019 to be used by the federal and state governments in their town planning and management. This concept had been absorbed into the Fourth National Physical Plan 2021-2040 (NPP4), which mainstreamed climate change agenda into the planning, emphasising on the need to enhance adaptive measures to increase the country's readiness to face climate change impact in the future.

Cities & Built Environment

PLANMalaysia had also prepared the 'Planning Guidelines for Disaster Resilient Cities in Malaysia' in 2019, which is used at the federal, state and local levels to reduce the risk of natural disasters through spatial planning and land use. The ultimate purpose is the building of resilient cities. The planning guidelines are aimed at (1) providing references to identify the level of disaster resilience of cities; (2) proposing a method of measuring the level of disaster resilience of cities; and (3) proposing a mechanism for the management and implementation to achieve disaster resilient status of towns and cities in Malaysia.

The PWD of Malaysia as the implementing agency for the development of public infrastructure has introduced various standards, guidelines and initiatives towards sustainable development that support the seven goals in the Sustainable Development Goals (SDGs). They have revised the 'JKR Sustainability and Green Mission 2.0' in 2017 covering all the types of development. The 'JKR Strategic Plan 2021-2025' was developed to ensure the delivery of development projects and asset management are at an excellent level and in line with the SDGs and Life Cycle Cost (LCC).

PWD of Malaysia has also issued various guideline documents as well as SIRIM standards to be used as a reference in the construction industry. Therefore, in order to maintain the commitment given, a new Sustainable Development Policy Book 2021-

2025, has been developed to continue to be inspirational towards achieving set targets. PWD of Malaysia has also adopted the Environmental Management System ISO 14001: 2015 (Environmental Management System) for the implementation of infrastructure development projects located in environmentally sensitive areas.

A sustainable development rating scheme called the Green Rating (pH JKR) for building and road projects was established as a tool to measure the level of sustainability of a building and road in cities/towns. The 'JKR Standard: JKR/SIRIM 2: 2020 Green Rating for Residential and Non-Residential Building Facilities' was also launched to promote sustainable development and climate resilience development in the cities/towns.

The incidence of erosion and landslide at hill slopes may increase due to improper geotechnical work and planning in the development. The PWD of Malaysia's Sustainable Development Policy was therefore established to minimise and balance the earth cutting work at the built environments. The Erosion and Sedimentation Control Plan (ESCP) by DID Malaysia is also being implemented to reduce the erosion and sediments to be discharge into the rivers and ponds to prevent floods. Further to this, all the new development activities in flood prone areas must be approved by the 'National Physical Plan, Structure Plans and Local Plans' to protect the built environments and their surrounding areas.

Flooding is a common phenomenon in Malaysia. The recent devastating floods in the country are examples of disaster likely due to climate change and anthropogenic activities of urbanisation. Therefore, long-term solution plans to overcome flash flood problems is an important approach for sustainable development in the country. Stormwater Management and Drainage Master Plan (PISMA), which is one of the frameworks of action that adopt the MSMA concept for stormwater management, offers the preparation of short-term and long-term solution plans in a comprehensive manner to overcome the flash floods in built environments of cities/towns. The framework is used as guideline for the Local Authorities concern to systematically plan for the development of the Local Council. A total of 45 PISMAs have been planned under the RMK12, where 28 were completed with seven others in the development process, and 10 in the planning process.

Several drought events have occurred in Malaysia since the recorded most severe drought in 1997/1998. To cope with dry spell situations, PWD of Malaysia has established a guideline on "System Design for Water Efficient Use in Buildings" to be used by designer to design a system with less water. They are currently conducting wastewater recycling system studies for their selected projects.

To promote good practices of water demand management in the country, in 2022, SPAN through the Water Efficient Products Labelling Scheme (WEPLS) has encouraged the suppliers in the development and marketing of water efficient products as part of the water conservation measures, as well as to raise the awareness of the public on the availability of water efficient products.

In 2022, initiative has been taken by some city councils to address the issues of climate change. Think City together with UN-Habitat, Penang State Government, Penang Island City Council and DID Malaysia have initiated to be the pioneer of nature-based climate adaptation program for their urban areas. The program is to address the climate change issues of heat stress and flooding, whilst strengthening social resilience and institutional capacity.

As the most fastest growing economic zone in the southern tip of Peninsular Malaysia, Iskandar Malaysia is vulnerable to the disasters due to rapid urbanization and increasing population, and exposure to the coastal hazards. The Iskandar Regional Development Authority (IRDA) through the National Designated Entity of Malaysia was awarded by United Climate Technology Centre and Network (CTCN) Technical Assistance (TA) for the Development of a Multi-Hazard Platform (MHP) for forecasting local level climate extremes and physical hazards for Iskandar Malaysia.

Roads

There are various Standards Specifications for Road Works and technical guidelines used by PWD of Malaysia for road design. PWD implements the Environmental Management System (EMS) ISO 14001 for PWD projects, which requires the mandatory Environmental Impact Assessment (EIA) report, a priori to proposal submission. So far, climate related factors had not been incorporated into the current design criteria. However, the Highway Network Development Masterplan (HNDP) 2007 has already considered environmentally sensitive and flood prone areas for new and existing road development strategies, thus requiring deeper climate factor considerations. Besides this, other adaptation measures by PWD also include implementing Social Impact Assessment (SIA), Health Impact Assessment (HIA), Wildlife Impact Assessment (WIA) studies and other management plans required by relevant authorities in Malaysia, such as the Department of Environment (DOE), PLANMalaysia, PERHILITAN and Department of Minerals & Geosciences.

In the event of floods, the PWD's Disaster Operations Room (Bilik Gerakan Bencana JKR) will provide the alternative routes for road users. The PWD's e-disaster (e-Bencana) website also function as a database to identify recurring flooded areas. For future road projects, the pavement design incorporates predictive climate models in place of historical climate data, and the road alignment can be checked with revised historical flood maps and future projected flood maps. The drainage design for the roads shall comply with the MSMA. As of 31st December 2020, the total length of Federal Roads constructed and being maintained by PWD is approximately 20,018 km. There is also approximately 247,027 km of State Road constructed and being maintained by State PWD and other State Authorities. The degradation of the road conditions may be partially attributed to bad weather conditions. Overall, frequent and severe floods with increased wet situations would further deteriorate road conditions thus needing additional maintenance efforts.

In adapting to SLR, new roads at coastal areas should be constructed at higher base levels following future SLR estimations. Existing road formation levels should be reviewed with proper wall protection systems, wherever necessary. The requirements on buffer zones are to be reviewed, and the practice of including protective ecological engineering approaches such as mangrove plantation ought to be considered. For road projects planned at Environmentally Sensitive Areas (ESA) such as water catchment or coastal areas, EIA study is mandatorily required by DOE. Environmental Consultants whom shall be appointed by PWD to investigate and report all potential impacts from the proposed projects, are required to identify all required mitigation and adaptation measures to reduce the impact on the environment.

Rails

The current practice of wet and dry weather inspection by KTMB's patrolman is important and should be enhanced to further reduce the occurrences of railway operation disruption due to floods and dry spells.

Ports and Jetties

Several initiatives have been taken by The Navigation Security Section of Marine Department Malaysia in order to adapt to haze conditions experience at the ports during dry spell seasons. Some of these initiatives include the periodic dissemination of information through NAVTEX (NAVigational TEleX), monitoring of meteorological report from METMalaysia every six-hour, verbal information is made through operators of the Vessel Traffic Services (VTS), and staff members of The Navigation Security Section are always on standby.

The current adaptation measures to SLR for jetties include the construction and raising of existing rock revetment or bund, platform levels of jetty and walkway, construction of wave buffer such as offshore breakwater or geotube, dredging river channel or river mouth, and beach nourishment or replenishment.

Airports

For haze hazard that may occur during dry spells, the current actions conducted at the airports include the activation of the Emergency Control Centre (ECC) when visibility reading dropped to the critical level. Low Visibility Condition (LVC) operation will be declared and several actions, including closure of runway and withdrawal of airside activities, will be taken immediately until the LVC is improved. The Malaysian Fire and Rescue Department (JBPM) are also on standby mode with more than 12,500 personnel for the purpose of operations at the areas at risk of fire and causing haze.

Solid Waste Facilities

In Malaysia, sanitary *landfill* is still the common method for the treatment of municipal solid waste. Reduction of solid waste generation and solid waste recycling remains as the best solution in solid waste management of the country. The recycling rate in 2020 was at 30.7%, and the Government is aiming to further increase the rate to 40% by 2025. This is in line with the National Cleanliness Policy 2019 to reduce solid waste pollution as well as to promote the circular economy and waste-to-wealth initiatives. This initiative will help to reduce the amount of solid waste going to the landfills hence reducing the risk of leachate seeping into nearby water catchment areas.

Sewerage Facilities

Adaptation to floods in the sewerage sector should be taken during the planning and operational stages. The Malaysian Sewerage Industry Guidelines (MSIG) has specified that all the STPs and NPSs shall be constructed above the designed flood level. Adequate drainage system within the STP and NPS compound, should be designed by factoring in climate change. Apart from that, installation programs of the Early Warning System (EWS) and the Supervisory Control and Data Acquisition (SCADA) system at critical STPs and NPSs have been implemented for the purpose of online operation monitoring. A Standard Operating Procedure (SOP) and Emergency Response Plan (ERP) shall be established and readily available to act during severe flood events.

Water Supply Facilities

Adequate treated water supply capacity is essential to meet the increasing socio-economic demand for water. A reserved margin of 15% of treated water in each state in Peninsular Malaysia is targeted to ensure adequate supply of water during dry spells. Adequate number and capacity of WTPs have to be made available to achieve this reserved margin. Protection of the facilities at the WTPs from floods and saltwater intrusion, as well as regular maintenance, are necessary. For extreme dry spells, sufficient water level at the intake points is required.

For the Klang Valley, where the largest country's economic activity is located and most impacted during dry spells, Air Selangor Sdn Bhd has identified new alternative water sources to ensure sustainable water supply in the region. A total of five to ten existing tin mining ponds located in the district of Sepang and Petaling have been identified as potential water sources in the form of 'Off-River Storage Facility' (ORS) through a project called the Rasau Water Supply Scheme. The scheme is expected to produce clean water supply of up to 700 MLD to the Klang Valley by the first stage of completion in 2024. In Selangor, the government is rolling out a 10-year plan in 2023 to study and implement an interconnected system linking the 98 lakes in the state, with river basins as part of a state-wide water resources scheme. As part of the ORS, the Hybrid Off-river Augmentation System (HORAS), was constructed in Selangor in 2014. The Selangor State Government has identified the HORAS 3000 project as a long-term solution for the water resources development to be utilized by the year 2065.

Another successful adaptation measure is the Pool Water Pumping Operation (OPAK) initiated by the Selangor Water Management Board (LUAS) at Bestari Jaya, Selangor, following the period of dry weather conditions and the drop in the dam water level in 2014. Since then, the OPAK has continued to be setup at other river basins, as an additional supplementary water source to increase river capacity and optimize dam water release. In 2016, the OPAK was successfully used to overcome the water supply disruption problem in Selangor River when it experienced a severe drop in the river water level.

Flood Relief Centres

The National Disaster Management Agency (NADMA), as the one-stop agency for disaster management, along with the states' disaster management mechanism, manages disaster relief and recovery during floods and other disasters in the country. The disaster management is continuing improved with lessons learnt from each disaster including the provisions of heavy rainfall forecast by MET Malaysia and early warning of floods by DID Malaysia, as well as the management of relief centres by the

Department of Social Welfare. The risk of flooding to the relief centres needs to be continuing assessed to ensure safety of these centres from floods.

4.9 Energy

4.9.1 Impact and Vulnerability

Electricity Generation, Transmission and Distribution

Rapid development and steady economic growth in the country over the past decades, have contributed to a healthy increase in demand for electricity generation. Currently, there are a total of 33 power plants (21 thermal power plants and 12 hydropower plants), 86,468 substations and 33,668 transmission towers located in Peninsular Malaysia. In Sabah, there are one hydropower plant and five thermal power plants, while in Sarawak there are five hydropower plants and five thermal power plants. The power plants mentioned above are those with 50 megawatts and above of capacity.

Floods

Based on the flood areal extent maps, three hydropower plants from Perak and Kelantan, and one thermal power plant from Selangor, were assessed to be vulnerable to floods at baseline timeline (1971-2000). The same four plants were also projected to be vulnerable to floods up to 2100. The projected number of substations in Peninsular Malaysia vulnerable to floods could substantially increase from 5,897 substations at the baseline timeline (1971-2000) to 7,093 substations up to 2100.

Extreme Wet and Dry Spells

High rainfall at dam catchments increases water storage in the hydropower dams and subsequently could lead to dam overflow and structural failure. At the other extreme, a prolonged dry spell will reduce the water storage in dams, leading to insufficient water for operating hydropower plants. Both floods and dry spells, could also affect the operations of thermal power plants. Dry spells will disrupt the cooling process of the plants, while floods will affect the plant infrastructure.

Based on the projected extreme wet weather in Peninsular Malaysia, the 12 hydropower plants located in Perak, Kelantan, Pahang and Terengganu could be prone to upstream floods at some particular years throughout the century (Table 4.52 & Figure 4.11). The same eight hydropower plants that are located in Perak and Pahang could be facing dry spells risks, when the projected extreme low rainfalls could happen at some particular times during the mid-century and late-century in the future.

There are eight hydropower plants, four in Sabah and four in Sarawak (including one under construction), were also projected to be flood prone at some particular future years throughout the century (Table 4.52 & Figure 4.12). The same four hydropower plants located in Sarawak could be facing dry spell risks as well for the same period (Table 4.53).

Table 4.52: Projected Number of Hydropower Plants Affected by Extreme Wet Weather by Early-Century, Mid-Century and Late-Century in Malaysia

State	Projected Number of Hydropower Plants Affected by Extreme Wet Weather (by Early-Century, Mid-Century and Late-Century)
Perak	4
Kelantan	1
Pahang	4
Terengganu	3
Sabah	4
Sarawak	4
TOTAL	20

Table 4.53: Projected Number of Hydropower Plants Affected by Dry Spells by Early-Century, Mid-Century and Late-Century in Malaysia

State	Projected Number of Hydropower Plants Affected by Dry Spells		
	By Early-Century	By Mid-Century	By Late-Century
Perak	0	4	4
Pahang	0	4	4
Sarawak	4	4	4
TOTAL	4	12	12

For thermal power plants, there are 10 plants expected prone to floods due to extreme wet weather at some particular years of certain future periods (early-century, mid-century and/or late-century) as shown in Table 4.54. It is estimated that six of these plants could be facing dry spell risks at some particular years of certain future periods (mid-century and/or late-century) based on the projected extreme future low rainfalls (Table 4.55).

Table 4.54: Projected Number of Thermal Power Plants Affected by Extreme Wet Weather by Early-Century, Mid-Century and Late-Century in Malaysia

State / Federal Territory	Projected Number of Thermal Power Plants Affected by Extreme Wet Weather		
	By Early-Century	By Mid-Century	By Late-Century
Selangor	1	1	2
Johor	2	0	2

State / Federal Territory	Projected Number of Thermal Power Plants Affected by Extreme Wet Weather		
	By Early-Century	By Mid-Century	By Late-Century
Negeri Sembilan	**0**	**2**	**2**
Perak	**0**	**1**	**0**
Pulau Pinang	**0**	**2**	**0**
Federal Territory (Putrajaya)	**0**	**1**	**1**
TOTAL	**3**	**7**	**7**

Table 4.55: Projected Number of Thermal Power Plants Affected by Dry Spells by Early-Century, Mid-Century and Late-Century in Malaysia

State / Federal Territory	Projected Number of Thermal Power Plants Affected by Dry Spells		
	By Early-Century	By Mid-Century	By Late-Century
Selangor	0	NONE	1
Johor	0	2	2
Negeri Sembilan	0	2	2
Federal Territory (Putrajaya)	0	1	1
TOTAL	0	5	6

Sea Level Rise

Based on the projected SLR, there are 4,137 out of 86,468 substations along the coastal areas of Peninsular Malaysia currently exposed to coastal inundation risks. This number is expected to increase to 4,991 (+20.6%) and 8,003 (+93.4%) by 2050 and 2100, respectively.

There were three thermal power plants projected to be prone to SLR at current baseline (2022) (Table 4.56). These three plants were also projected to be affected by SLR by 2050 and 2100. The total numbers of affected plants are estimated to increase to four plants by 2050 and seven plants by 2100.

Table 4.56: Projected Number of Thermal Power Plants Affected by SLR at Current Timeline (2022), 2050 and 2100 in Peninsular Malaysia

State	Type of Power Plants	Projected Number of Thermal Power Plants Affected by SLR		
		Current Baseline (2022)	2050	2100
Selangor	Gas-fired	1	1	1
	Coal-fired	1	1	1
Johor	Gas-fired	0	0	2
Negeri Sembilan	Coal-fired	0	1	1
Pulau Pinang	Gas-fired	1	1	1
	Oil-fired	0	0	1
TOTAL		3	4	7

Oil and Gas

A total of 1,140 PETRONAS assets, which comprise of 76 core business (13 upstream business – inland only, 10 gas business, and 53 downstream business – including petrol stations, depots and terminals) and 1,064 retail stations, were assessed for their vulnerability to climate change.

Floods

The number of probable impacted PETRONAS assets in the country was projected to increase from the baseline timeline (1971-2000) of 111 to 132 up to 2100. The projected assets that are at risk at current timeline include two core business assets in Kuala Lumpur, and three operation sites and offices in Sarawak. The balance of the 106 potential assets are mostly retail stations, with 70 located in Peninsular Malaysia and 36 in Sabah and Sarawak. Up to 2100, no change is expected in the projected potential impacted assets for Upstream, Downstream and Gas businesses except for the retail station assets that could increase from 106 to 127. These include 90 assets located in Peninsular Malaysia and 37 in Sabah and Sarawak.

Dry Spells

All the inland PETRONAS assets were assessed for future dry spell hazard, except for the retail stations organised under PETRONAS Dagangan Berhad (PDB). A total of 70 assets were projected to be affected by dry spells in some particular years by late-century. These comprised of 12 upstream businesses, 48 downstream businesses and 10 gas businesses. Upstream business has more onshore offices that are estimated not vulnerable to water stress, while downstream business and gas business have more temperature sensitive equipment and thus are more vulnerable.

Retail stations are expected not to be significantly affected due to the nature of their business.

Extreme High Temperature

Extreme high temperature would lead to heat stress on operations and the workability of staff. The potential changes in future temperature were therefore analysed for the PETRONAS assets located at Gurun, Melaka, Pengerang, Gebeng, Kerteh, Bintulu, Miri and Labuan, which are the areas where PETRONAS has the largest footprints. It was projected that Gurun could record the highest maximum temperature of 39.5°C in late-century. This was followed by Melaka, where a maximum temperature of 38.1°C is expected in the same period. At Gurun, there were seven occasions of spike in temperature projected to occur by late-century, and reaching a maximum temperature of 38.0°C every 3 to 5 years. Significant projection was also found in Melaka, where 11 occasions of spike in temperature, reaching a maximum temperature of 38.0°C (late-century), are expected. High maximum temperatures range from 35.0°C to 38.0°C by 2100 were also projected for Gebeng, Labuan and Miri.

In terms of temperature gradient rise, in Melaka, where PETRONAS Penapisan (Melaka) Sdn Bhd is located, it was projected to experience the highest temperature gradient rise of 0.36°C per decade. Meanwhile, Pengerang, Labuan and Bintulu are among the areas that were also projected to be susceptible to high gradients of temperature rise of 0.22-0.26°C per decade.

The assets located in these areas could be vulnerable to significant changes in temperature. Nevertheless, detailed modelling and analysis is required for a better understanding of their vulnerabilities and risks.

Sea Level Rise

The projected number of assets to be affected by SLR is expected to increase from the current timeline (2022) of 44 assets to 55 assets by 2050. More significant increment was projected by 2100, where a total of 83 assets (5.0% from the upstream business, 4.0% from the downstream business, and the remaining 91.0% are the retail stations) are expected to be affected. The majority of PETRONAS assets that have the most probability of being affected are its retail stations since they are widely distributed throughout the country. It was found that the top four states affected are Selangor (19 stations), Penang and Johor (14 stations each); and Kedah (12 stations). Notable PETRONAS assets from Upstream Business that could be potentially at risk were projected in Bintulu, Miri and Kerteh; while from Downstream Business, the same were projected in Pulau Pinang and Johor.

4.9.2 Adaptation Measures

Electricity Generation, Transmission and Distribution

The following adaptation measures have been implemented for the electricity sector:

Floods

- An integrated catchment management policy, procedures, and guidelines to regulate power supply among the catchments during floods;
- Flood drills to improve the standard operating procedures, better managed critical situations and safely restore the electricity supply;
- Integrated Community-Based Disaster Management (ICBDM) program;
- Prompt shutdown of affected substations through the early warning systems to avoid/prevent/contain damages;
- Installation of protective measures around the substations such as flood walls, flood gates, flap gates and pumping systems to reduce the water level inside the substation area;
- Raised heights of transmission towers;
- Conduct necessary hydrological review to establish the new Probable Maximum Precipitation (PMP) and Probable Maximum Flood (PMF) values for Hydropower Plant;
- Review and revise of the design PMF and spillway capacity by updating from previous study for Kenyir Dam and latest Kenyir Dam incident; and
- Implement Risk Informed Decision Making (RIDM) approach to ensure Sustainable Hydropower Dam Safety Management for Kenyir

Dry Spells

Temporary storage tanks or/and alternative water sources (groundwater, treated saline water, and recycled brackish groundwater and municipal wastewater) as an addition to the existing water sources and increasing storage volumes to ensure ample water supply to thermal power plants at all times, especially during dry weather conditions.

4.10 Public Health

4.10.1 Impact and Vulnerability

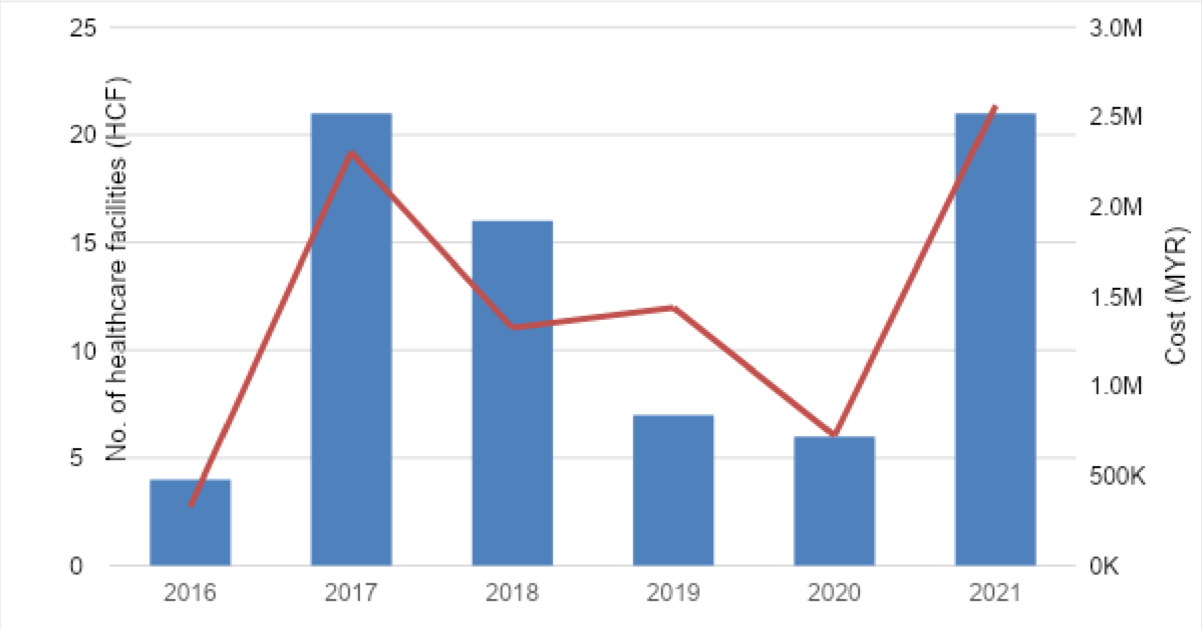
Healthcare Facilities

The Malaysia healthcare systems have been improving over the years, with a doctor to patient ratio of 1:420 as at 2021, dispersed throughout 367 hospitals including special medical institutions (158 public and 209 private) and 11,117 clinics (2,895 public and 8,222 private). Climate change does pose a significant threat to these facilities, where extreme weather events have disrupted operations, making provision of high-quality services difficult. The vulnerability of healthcare facilities therefore needs to be taken into cognizance to enable advanced planning and implementation of adaptive management strategies for more resilient towards challenges arising.

Floods

Floods in December 2021 to January 2022 had affected 138 MOH healthcare facilities with an estimated RM 11,297,000 of infrastructure damage. Until July 2022, a total allocation of RM 2,502,195 was utilised for the replacement of damaged assets in the four major affected states (Selangor, Kelantan, Pahang, and Terengganu). Over the past six years (from 2016 to 2021), a total of RM 8,684,922 had been allocated for maintenance and repairing works of 75 healthcare facilities affected by floods (Figure 4.16).

Figure 4.16: Maintenance and Repairing Cost of the Affected MOH Healthcare Facilities from 2016 to 2021



Impact of floods on the MOH healthcare facilities was assessed at 146 hospitals (including special medical institutions) and 1,141 health clinics located at the 37 river basins in Malaysia (Table 4.57). The assessment showed that 17 hospitals and 125 health clinics were prone to floods at baseline timeline (1971-2000). These numbers are expected to increase to 19 hospitals and 149 health clinics, respectively, up to 2100. In Peninsular Malaysia, two additional hospitals located at the Johor River basin and Kerian River basin are expected to be prone to floods up to 2100. Health clinics in Peninsular Malaysia could be more vulnerable to floods with an increment of 22 flood prone health clinics expected up to 2100, especially in Kedah, Perak, Pahang and Kelantan River basins. However, no significant changes were projected for Sabah and Sarawak for the same period.

Table 4.57: Projected Number of Flood Prone MOH Hospitals and Health Clinics at Baseline Timeline (1971-2000) and up to 2100 in Malaysia

River Basin	Hospitals			Health Clinics		
	Total Assessed	Baseline Timeline (1971-2000)	Up to 2100	Total Assessed	Baseline Timeline (1971-2000)	Up to 2100
Peninsular Malaysia						
Kedah	17	0	0	120	7	10
Muda		0	0		5	5
Perak	15	1	1	99	13	17
Kerian		0	1		0	2
Selangor	19	0	0	112	1	1
Kelang		0	0		7	7
Kesang	3	0	0	33	0	0
Linggi	7	0	0	51	1	2
Johor	12	0	1	103	0	0
Muar		2	2		3	4
Batu Pahat		0	0		2	3
Pahang	11	2	2	93	7	10
Kuantan		0	0		2	4
Dungun	6	0	0	53	1	1
Kemaman		1	1		2	2
Setiu		0	0		0	0
Kelantan	9	2	2	103	15	20
Sub-Total	*99*	*8*	*10*	*767*	*66*	*88*
Sabah						
Sg Kalumpang	24	0	0	133	0	0
Sg Padas		2	2		5	5
Sg Sinsilog		0	0		0	0
Sg Sugut		0	0		1	1
Trusan Kinabatangan		0	0		0	1
Sg Segama		0	0		0	0
Sg Tuaran		0	0		0	0
Sg Papar		1	1		1	1
Sg Labuk		0	0		1	1

River Basin	Hospitals			Health Clinics		
	Total Assessed	Baseline Timeline (1971-2000)	Up to 2100	Total Assessed	Baseline Timeline (1971-2000)	Up to 2100
Sg Abai		0	0		0	0
Sub-Total		*3*	*3*		*8*	*9*
Sarawak						
Batang Rajang	23	4	4	241	16	16
Batang Baram		0	0		4	4
Batang Oya		1	1		3	3
Sg Sarawak		0	0		9	10
Batang Sadong		0	0		5	5
Batang Lupar		1	1		3	3
Sg Limbang		0	0		1	1
Batang Kemena		0	0		5	5
Batang Samarahan		0	0		2	2
Batang Saribas		0	0		3	3
Sub-Total		*6*	*6*		*51*	*52*
TOTAL	146	17	19	1,141	125	149

Sea Level Rise

Impact of SLR on the MOH healthcare facilities was assessed at 147 hospitals and 1,143 health clinics in the country (with additional one hospital and two health clinics from Labuan) (Table 4.58). The assessment showed that four hospitals were prone to SLR at current timeline (2022). This number is expected to remain the same by 2050, however, four more hospitals, one each from Perak, Selangor, Sabah and Sarawak, are expected to be prone to SLR by 2100. Health clinics could be more vulnerable to SLR inundations. This is shown by the projected increments of 5 and 37 affected health clinics by 2050 and 2100, respectively.

Table 4.58: Projected Number of MOH Hospitals and Health Clinics Affected by SLR at Current Timeline (2022), 2050 and 2100 in Malaysia

State / Federal Territory	Hospitals				Health Clinics			
	Total Assessed	Current Timeline (2022)	2050	2100	Total Assessed	Current Timeline (2022)	2050	2100
Johor	12	1	1	1	103	5	6	7
Kedah	10	1	1	1	69	3	4	6
Kelantan	9	0	0	0	103	0	0	0
Melaka	3	0	0	0	33	0	0	1
Negeri Sembilan	7	0	0	0	51	0	0	0
Pahang	11	0	0	0	93	0	0	0

State / Federal Territory	Hospitals				Health Clinics			
	Total Assessed	Current Timeline (2022)	2050	2100	Total Assessed	Current Timeline (2022)	2050	2100
Perak	15	0	0	1	99	5	6	10
Perlis	1	0	0	0	11	1	1	1
Pulau Pinang	6	0	0	0	40	1	1	5
Selangor	13	2	2	3	84	13	15	20
Terengganu	6	0	0	0	53	1	1	3
Sabah	24	0	0	1	133	0	0	5
Sarawak	23	0	0	1	241	0	0	8
Federal Territories (Kuala Lumpur and Putrajaya)	6	0	0	0	28	0	0	0
Federal Territory (Labuan)	1	0	0	0	2	0	0	0
TOTAL	**147**	**4**	**4**	**8**	**1,143**	**29**	**34**	**66**

Vector Borne Diseases

Dengue

Malaysia is a dengue endemic country where cases are reported all year round. Dengue is one of the mandatory notifiable diseases for medical practitioners in Malaysia under the Prevention and Control of infectious Diseases Act 1988 (Act 342). All premises in Malaysia are prohibited from harbouring disease bearing insects including Aedes mosquitoes under Destruction of Disease-Bearing Insects Act 1975 (Act 154).

The El Niño events observed in 2014-2016 and 2018-2019 had affected Malaysia's local climate and become a crucial climate driver to dengue outbreaks. There were 130,101 dengue cases reported in 2019, which was the highest occurrence of dengue cases in Malaysia for the past 20 years, compared to 120,836 cases in 2015 (Figure 4.17). However, despite the alarming number of dengue cases, the dengue death in 2019 (182 deaths) was reported to be fewer compared to 2015 (336 deaths). The case and death continued to decrease since then, and achieved the lowest in 2021. Since 2018, dengue case fatality rate (CFR) continues to decrease below the CFR target of 0.2% until it reached the lowest of 0.08% in 2021 (Figure 4.18). However, the drastic decrease in 2020-2021 could have probably been attributed to the reduced population mobility enforced during the Movement Control Order (MCO) following the COVID-19 pandemic.

Figure 4.17: Dengue Cases and Deaths in Malaysia from Year 2000-2021

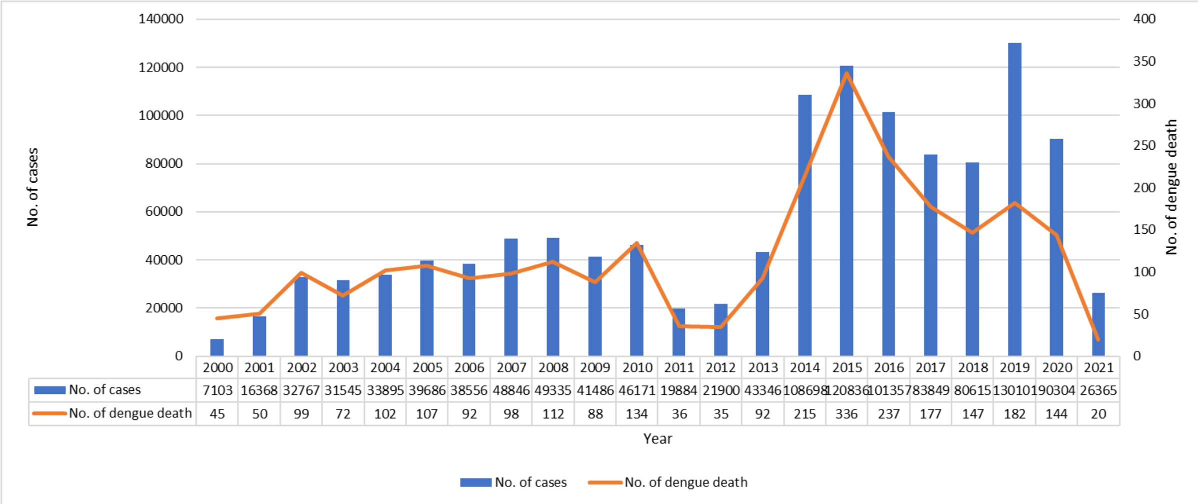
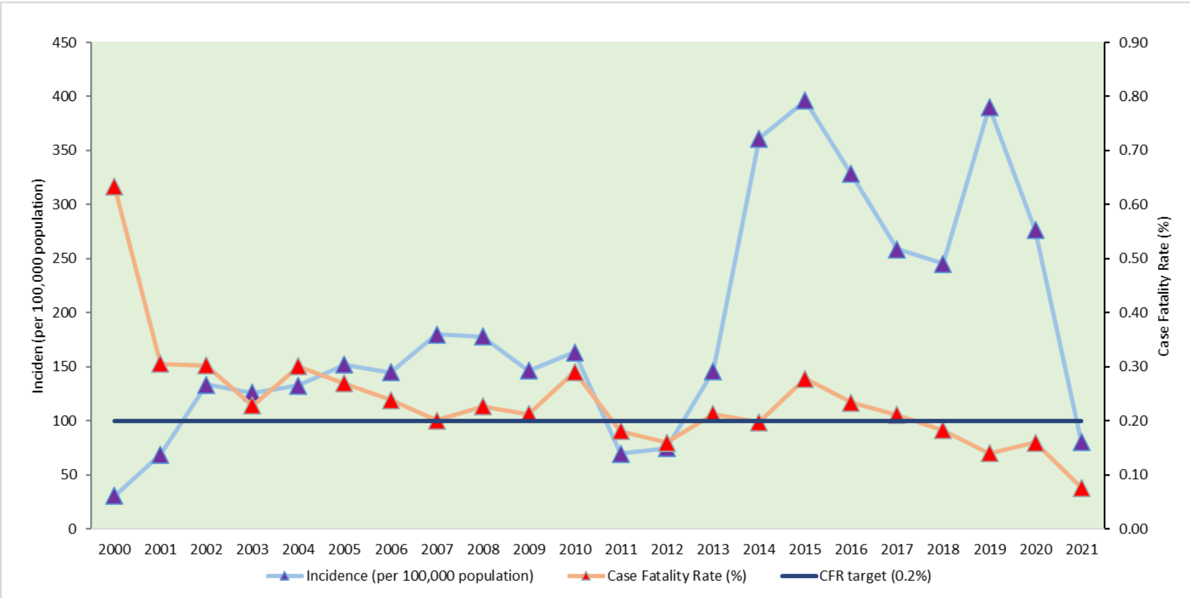


Figure 4.18: Dengue Incidence and Case Fatality Rate in Malaysia for 2000-2021



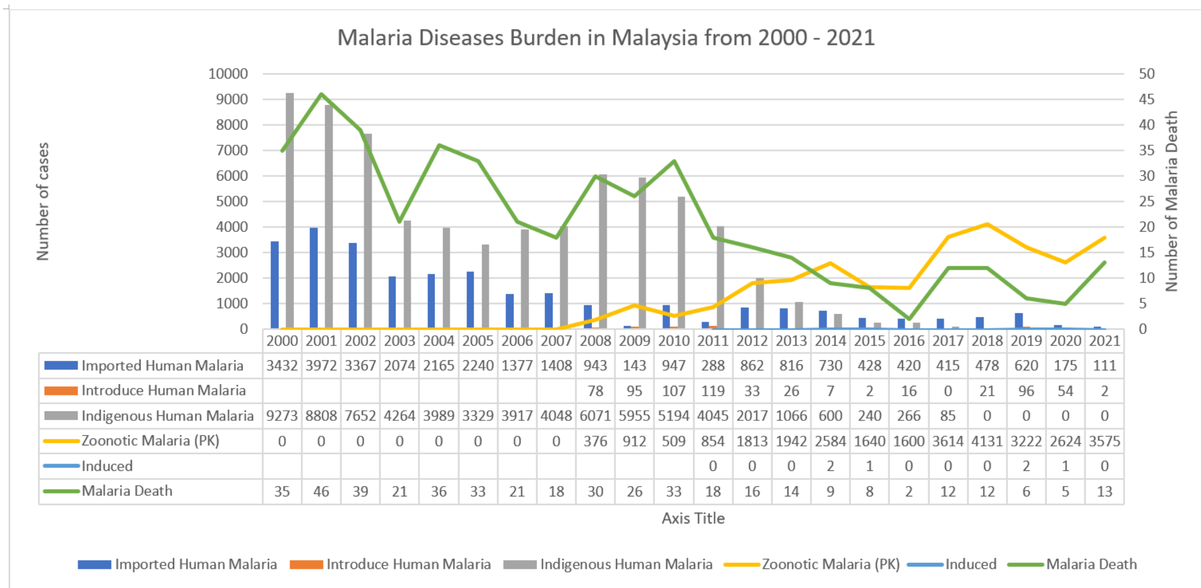
Malaria

Malaysia has come a long way in the malaria prevention and control programs since the discovery of malaria transmission in 1900s. The requirement to notify malaria cases is governed by the Prevention and Control of Infectious Diseases Act (1988) under Section 10 (c) Act 342. Even though human malaria cases were drastically reduced since the introduction of malaria eradication programs in 1960, Malaysia has been moving into addressing simian malaria caused by the *Plasmodium knowlesi*.

Malaysia is currently on track for malaria elimination by successfully sustaining the status of zero indigenous case of human malaria, for four consecutive years since

2018. Despite achieving the status, Malaysia is facing the increasing trend of zoonotic malaria from *Plasmodium knowlesi* infection. Zoonotic malaria cases had increased ten-fold from less than 400 in 2008 to over 4,000 in 2018. Although cases showed reducing trend in 2019 and 2020, but it had unexpectedly increased to 3,575 cases in 2021 with 13 deaths (Figure 4.19).

Figure 4.19: Malaria Disease Burden in Malaysia from 2000-2021 (Source: Vector Borne Disease Sector, Ministry of Health Malaysia)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Imported Human Malaria	3432	3972	3367	2074	2165	2240	1377	1408	943	143	947	288	862	816	730	428	420	415	478	620	175	111
Introduce Human Malaria									78	95	107	119	33	26	7	2	16	0	21	96	54	2
Indigenous Human Malaria	9273	8808	7652	4264	3989	3329	3917	4048	6071	5955	5194	4045	2017	1066	600	240	266	85	0	0	0	0
Zoonotic Malaria (PK)	0	0	0	0	0	0	0	0	376	912	509	854	1813	1942	2584	1640	1600	3614	4131	3222	2624	3575
Induced												0	0	0	2	1	0	0	0	2	1	0
Malaria Death	35	46	39	21	36	33	21	18	30	26	33	18	16	14	9	8	2	12	12	6	5	13

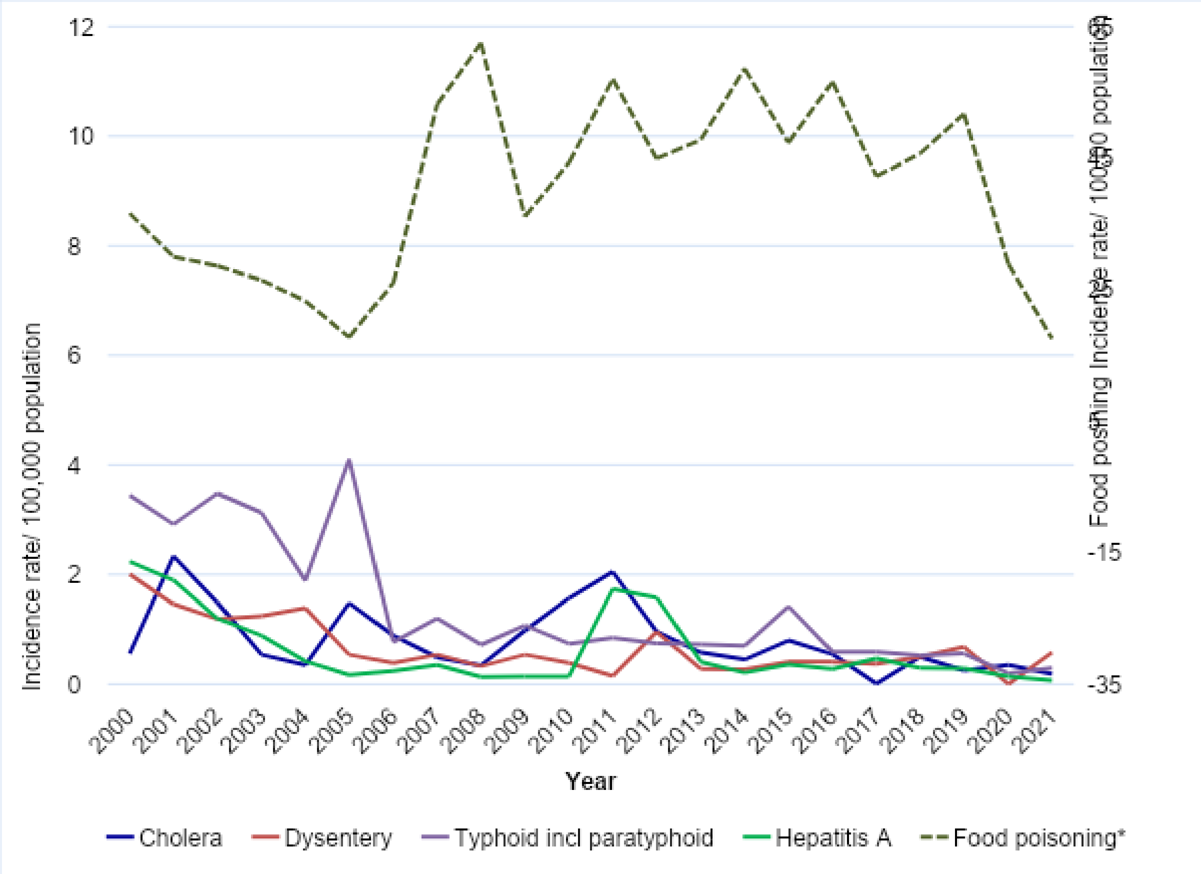
There are evidences that malaria in warmer regions has shifted toward higher altitudes, for example, the malaria susceptibility index and zoning analyses found that areas located along the Crocker Range of Sabah were highly susceptible to *Plasmodium knowlesi* infections. Besides, the changes in land use, deforestation, migration and travelling were at the same time, also identified as the main factors influencing zoonotic malaria transmission.

Food and Water Borne Diseases

Food and Water Borne Disease (FWBD) is a notifiable disease under Section 10 (c) Act 342, the Prevention and Control of Infectious Diseases Act (1988). The five notifiable FWBDs in Malaysia are food poisoning, typhoid (including paratyphoid), cholera, dysentery, and hepatitis A. These diseases usually appear as sporadic outbreaks, and the incidences are linked to water sanitation and hygiene including the unavailability of safe potable water supply in some rural areas.

The trend of FWBD has been fluctuating over the past 20 years (Figure 4.20). The overall incidence of FWBD was reported with lower rate over the past 5 years. This can be specifically seen in the trend of cholera and typhoid including paratyphoid.

Figure 4.20: Food and Waterborne Diseases (FWBD) Incidence Rate in Malaysia for 2000-2021 (Source: VPD/ FWBD Sector MOH)

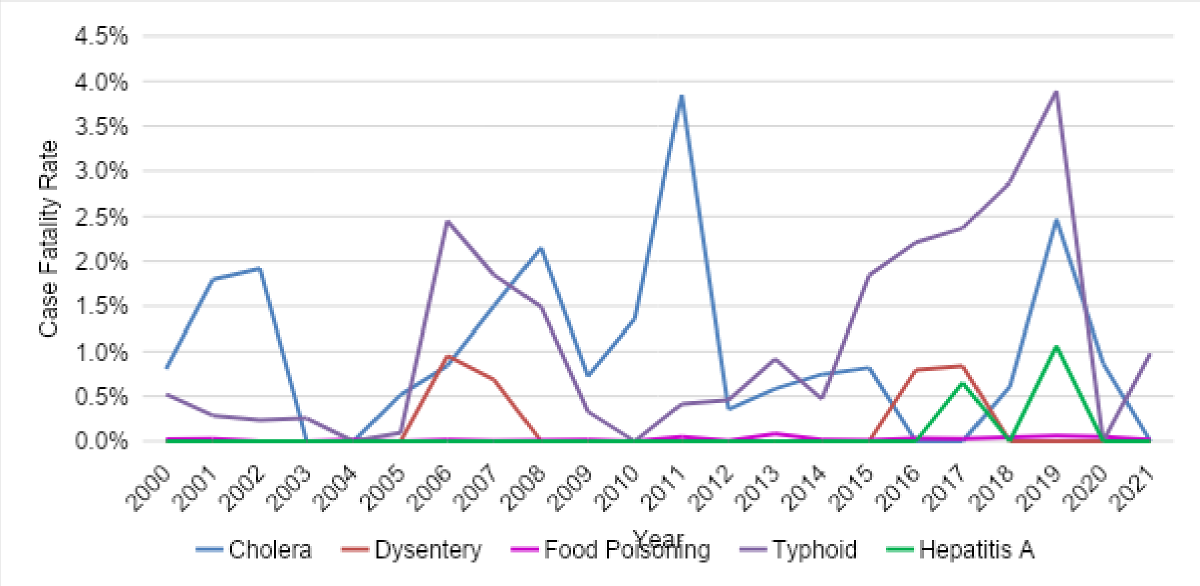


Disruptions of infrastructure, water supply and sanitation systems may exacerbate the risks of FWBD transmission. This was the case during the 2014 flood when the typhoid fever and cholera transmission incidence rates were higher during post flood (2015) with the incidence rates of 1.42 and 0.80 per 100,000 population, respectively.

The incidence rate of food poisoning fluctuated but followed a consistent pattern over the past 10 years before the COVID-19 pandemic in 2020-2021. During the COVID-19 pandemic, the incidence rate significantly declined from 51.74 per 100,000 population in 2019 to 17.54 per 100,000 population in 2021. This was likely a result of the enforcement of MCOs that reduced population mobility during the COVID-19 pandemic.

Minimal number of deaths were reported for FWBD in the past ten years, especially for food poisoning, dysentery and hepatitis A with almost zero reporting case (Figure 4.21).

Figure 4.21: Food and Waterborne Diseases Case Fatality Rate in Malaysia for 2000-2021 (Source: VPD/ FWBD Sector MOH)

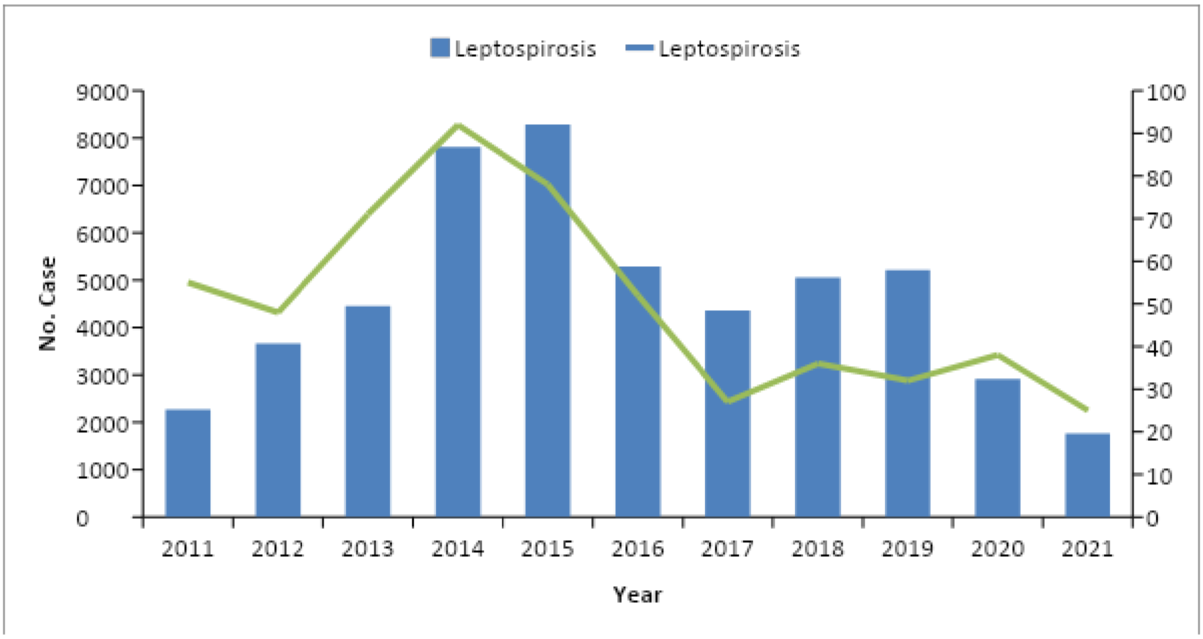


Leptospirosis

Leptospirosis is the most widespread emerging infectious zoonosis, especially in tropical regions, affecting animals including livestock by its different manifestations and can cause considerable economic losses. Since 2011, leptospirosis is one of the mandatory notifiable diseases by medical practitioners in Malaysia under the Prevention and Control of infectious Diseases Act 1988 (Act 342).

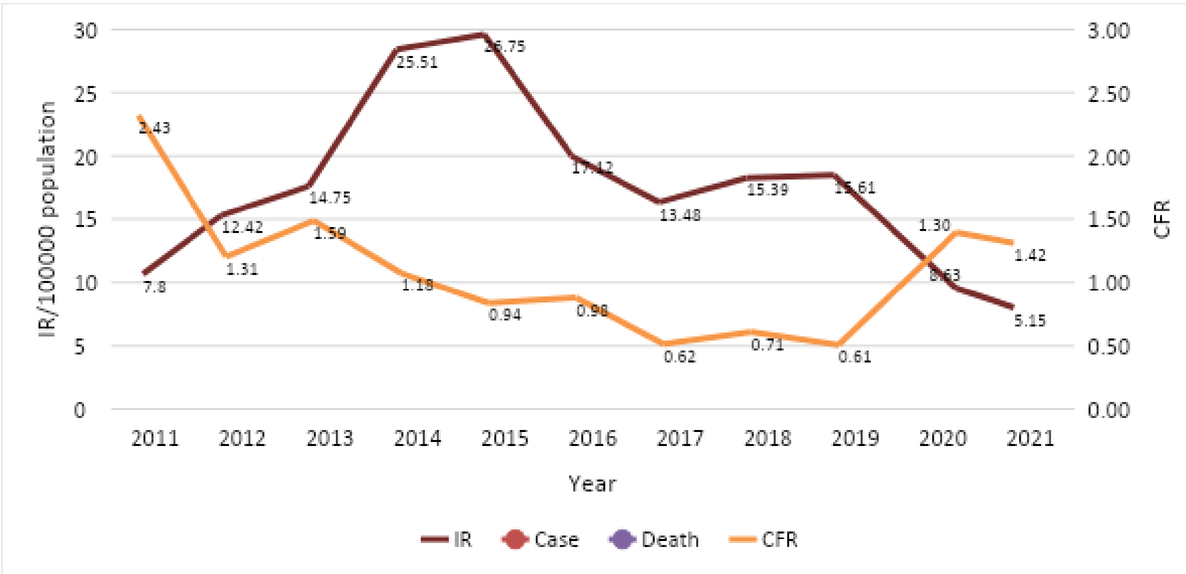
The incidence of leptospirosis was noted to increase in numbers since its recognition as a notifiable disease in 2011 (Figure 4.22). The highest number of cases was notified in 2015 after the large flood of December 2014 to January 2015, in the east coast and northern region of Peninsular Malaysia. The observed impacts demonstrated a complex influence of climatic factors on the dynamic of leptospirosis transmission between humans, zoonotic animals and the environment.

Figure 4.22: Leptospirosis Cases and Deaths from 2011 to 2021



Leptospirosis transmission was observed to be interrupted during the COVID-19 pandemic with incidence rate reduced from 15.61 per 100,000 population in 2019 to 5.15 per 100,000 population in 2021 (Figure 4.23). In contrast, the case of fatality rate showed increment from 0.61% in 2019 to 1.42% in 2021.

Figure 4.23: Trends of Leptospirosis Incidence and Case Fatality Rate from 2011 to 2021



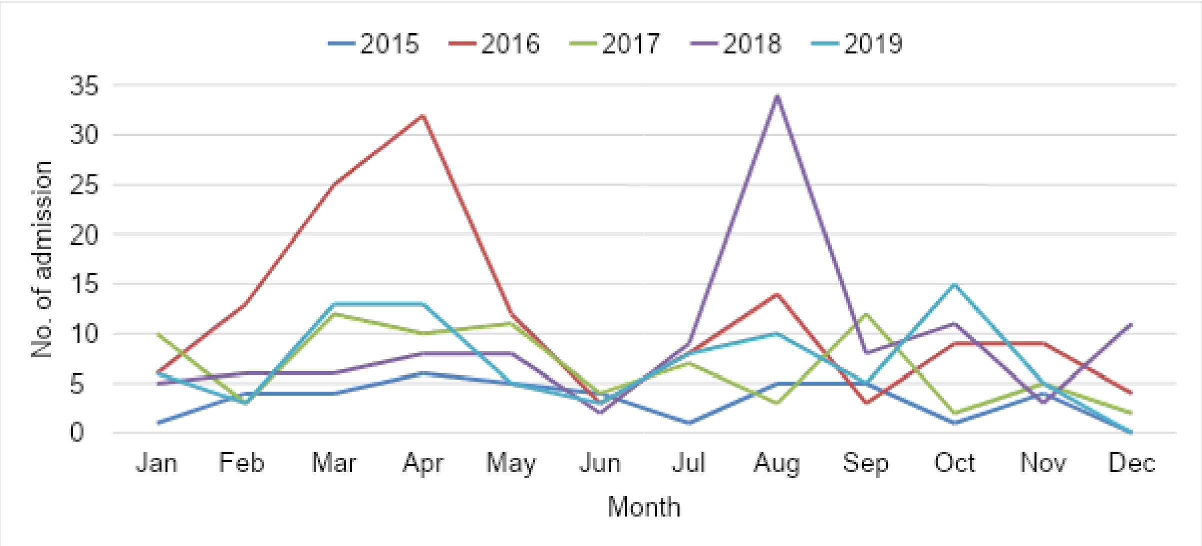
Heat Related Illness

Prolonged periods of lower precipitation, high humidity and higher-than-average temperature will have negative health impacts on human and livelihood. Over-exposure to high temperatures can cause an immediate effect or acute illness such as heat rash, heat cramps, exhaustion, syncope, heat stroke, and even death. Extreme temperatures can also aggravate chronic conditions such as cardiovascular, respiratory, and cerebrovascular disease, and resulting in increased excess mortality and hospitalisation.

Malaysia had experienced heatwave events in 2016 and 2019. The year 2016 was the hottest year ever in Malaysian history with the recorded maximum temperature of 39.3°C. This hot weather was strongly influenced by the natural climate variability of a strong El Niño from 2015 to 2016. Heatwaves were then recorded in the northern states of Peninsular Malaysia, Pahang, Kelantan, and Keningau, Sabah. There were 200 cases of heat related illness, including 22 cases of heat stroke (11%), 126 cases of heat exhaustion (63%), and 52 cases of heat cramp (26%) were reported during this heatwave episode (Ministry of Health Malaysia, 2016). In comparison to 2016, the heatwave episodes in 2019 were not as severe and prolonged.

Direct health effects from heat and light exposure are classified as Code T67 of the International Classification of Diseases 10th Revision (ICD-10). During the warmest years in Malaysia from 2015 to 2019, the highest number of hospital admission for ICD-10 Code T67 was recorded in 2016 (Figure 4.24).

Figure 4.24: Hospital Admission for Code T67 (Effects of Heat and Light) for 2015-2019 (Source: Health Informatics Centre, Ministry of Health Malaysia)



4.10.2 Adaptation Measures

Healthcare Facilities

Extreme weather events and climate related disasters such as floods have impacts on the healthcare infrastructure and facilities, as well as the operation of healthcare systems. The MOH has therefore planned to relocate flood prone healthcare facilities to higher ground in order to provide uninterrupted services during flood events. In Kelantan, which was the worst hit area during the 2014 flood, 12 of the severely impacted healthcare facilities were identified for re-development purposes. The healthcare facilities were relocated and rebuilt with more climate resilient design and structures.

Simultaneously, the Water and Sanitation for Health Facility Improvement Tool (WASH FIT) is being used as a risk-based approach to improve and sustain healthcare water, sanitation, hygiene and waste management, as well as facilitating care of the environment. The baseline WASH data collection was carried out in 2021 for the selected 146 MOH hospitals and special medical institutions. Using the WASH service ladders and the WASH FIT methodology, the MOH has also developed various national standards, guidelines, and accountability mechanisms for resilient facilities.

Vector Borne Diseases

Dengue

Since 2014, it is mandatory to have all registered dengue cases undergo confirmatory serology testing. The real time web-based on dengue surveillance systems such as e-notification, e-Dengue and Dengue Outbreak Management System (SPWD) are available for detailed information on the disease. The Dengue Virus Serotype Surveillance Program acts as a platform in sentinel surveillance of circulating dengue serotype. Vector control activities such as source reduction, community mobilization, and chemical and biological control, were successfully adopted through the Integrated Vector Management (IVM). The Disease Control Division of MOH has recently established the National Strategy Plan for Dengue Prevention and Control Program (2022-2025).

Malaria

Malaysia has ended the National Strategic Malaria Elimination Plan in 2021 with no indigenous case of human malaria reported for four consecutive years. However, Malaysia is still exposed to the risk of imported human malaria infection through influx of foreign workers, as well as increasing threats of zoonotic malaria infections. Therefore, five new adaptation strategies and approaches have been implemented to prevent the reintroduction of malaria in this country. These include (i) rural community participation on malaria programme, (ii) universal coverage on malaria diagnosis, treatment, and vector control, (iii) development of new malaria risk stratification based on receptivity and vulnerability, (iv) enhancement of malaria surveillance using GIS and remote sensing technology, and (v) strengthening entomological surveillance using GIS and remote sensing technology.

Necessary services and supplies such as vector control supplies and equipment storage are provided for the high-risk populations, which include the Orang Asli, mobile, migrant and other hard-to-reach populations, through the Malaysia National Malaria Prevention and Control Programme. For many years and is still continuing, local villagers and volunteers were recruited in assisting malaria surveillance and control activities at local level.

In 2016, the Malaysia FOCI (MyFOCI) system was developed to collect receptivity, vulnerability and malaria outbreak investigative data for foci stratification purposes. Subsequently, an online Malaysia Entomology and Pest Information System (myEntoPest) was also developed for the same purpose. All the data and information will be analysed through the Malaria Geo-Reference Information & Coordination System for Malaria Elimination (MAGICs.ME) with built-in prediction module for malaria risk mapping

Food and Water Borne Diseases

The Disease Control Division and Institute for Medical Research (IMR) under the MOH are the institutional members of the Global Salmonella Surveillance (GSS). The Disease Control Division is constantly improving its surveillance, investigation, and management of emerging and re-emerging diseases, allowing for immediate case notification and timely intervention. In May 2007, the National Crisis Preparedness and Response Centre (CPRC) was established. The centre is equipped with standard operating procedures for emergency and disaster management, and responsible for managing disease outbreak response activities.

The Prevention and Control of Infectious Disease Act (Act 342) took effect in 1988 is continually enforced. Establishment of an online notification system, e-notifikasi, has allowed early warning and better surveillance through continuous monitoring of FWBD and early detection of new outbreaks. Acute Gastroenteritis (AGE) surveillance is currently being implemented in the health facilities, and reported weekly at the district and state levels.

Leptospirosis

Under the Prevention and Control of Infectious Diseases Act 1988 [Act 342], the MOH had made it mandatory to notify all leptospirosis cases (both probable and lab-confirmed cases) through the *eNotifikasi* System, since 2011. Guidelines for the Diagnosis, Management, Prevention and Control of Leptospirosis in Malaysia was also developed in 2011 to provide disease information and guidance on diagnostic criteria, management of diagnostic samples and notification procedures. Laboratory tests are mandatory for all leptospirosis cases, particularly those requiring hospitalisation as well as fatal cases. At the same time, a real time web-based *eNotifikasi* and *eWabak* System for surveillance of leptospirosis is being implemented as part of enhancing the early warning process.

The control and prevention plan for leptospirosis is implemented through four strategies: (i) enhanced surveillance and sharing of information, (ii) coordinated multi-agencies prevention and control activities, (iii) risk reduction, and (iv) research and development.

Heat Related Illness

A National Heatwave Action Plan Technical Committee was set up to address the issue of extreme temperatures and heatwaves. A baseline definition and action plan for dealing with future heatwaves and extreme weather occurrences had then been established. As response to the 2016 heatwave, the MOH has established the Clinical Guidelines on Management of Heat-Related Illness in Health Clinics and Emergency and Trauma Departments to focus on the clinical management of heat-related illnesses.

In 2021, the MOH had issued an action plan on health risk management during heatwave, which acts as a guideline that incorporated health action throughout all phases of the heatwave. The National Disaster Management Agency (NADMA) will take over the heatwave management should a level 3 alert strike, as this is classified as a national emergency (ambient air temperatures higher than 40°C).

4.11 Gaps and Improvement Plan

The gaps identified from the NC3, the post NC3 specifics; the sectoral impact and vulnerability assessments with the gaps addressed in the NC4, and improvement plans for mitigating complexities resulting from climate change anomalies, are summarised in Table 4.59.

Table 4.59: Post NC3 Specifics, Gaps in NC4 and Improvement Plan

Area	Gaps in NC3	Post NC3 Specifics	Gaps in NC4	Improvement Plan
Flood	Lack of projected flood maps covering all the flood prone basins.	Closed the gaps; Flood areal extent maps for 17 river basins in Peninsular Malaysia, 10 river basins in Sabah and 10 river basins in Sarawak were developed for flood impact assessments of all sectors	Downscaled hydroclimate data for urban areas is not available	To be continued with the existing river basins with new AR6 data set; To conduct more refined downscaling modelling for urban areas
Dry Spell	Analysis of projected dry spells for vulnerability assessments need to be based on seasonal rather than annual scale, and with high spatial resolution.	Closed the gaps; Monthly and yearly rainfall indices (RVIs) were developed for the whole country for dry spell or extreme dry weather, and extreme wet weather, impact assessments of all sectors	Hydrological drought index is not as yet available or established	To be continued with the meteorological drought index with new AR6 data set; To develop hydrological drought index or similar indices for specific sectors
	Insufficient priority and detailed analysis of impacts of dry spell on dams and reservoirs.	Closed the gaps; Monthly and yearly rainfall indices (RVIs) were developed for all the dam locations and reservoir catchments for dry spell or extreme dry weather impact assessments	Projected dam inflow is not available	Enhance land surface hydrological modelling for producing projected river flow at specific reservoirs / dams

Area	Gaps in NC3	Post NC3 Specifics	Gaps in NC4	Improvement Plan
Sea Level Rise	Insufficient coastal hydrodynamic simulation that incorporates sea level rise impacts for vulnerable coastal regions in Malaysia.	Used static model only for inundation	No hydrodynamic modelling data. However, TWO dimensional (2D) numerical coastal hydrodynamic model under RCP8.5 scenario for time horizon 2100 was tested in Kelantan, Terengganu, Perlis, Kedah and Penang.	Coastal flood inundation and saltwater intrusion simulations using TWO dimensional (2D) numerical coastal hydrodynamic model
Sea surface temperature	Lack of sea surface temperature map	Not developed due to lack of financial resources	Lack of Sea surface temperature dataset and impact studies on fishery, oil & gas and marine resources sectors	Establish models and tools to provide future sea surface temperature dataset
Integrated hazards	The combined impacts of sea level rise, storm surges, abnormally high tides and high rainfall which could lead to severe flooding are not well understood.	Due to budget constraint, storm surge modelling analysis will only start in 2024/2025.	No integration results were used in assessment due to the unavailability of storm surge data.	Integrated SLR, storm surge and high rainfall events using a numerical river and coastal hydrodynamic model for selected river basins.
	Inadequate information of assets in vulnerable areas for each sector.	Additional sub-sectors have been assessed; More assessments have been carried out using the projected hydroclimatic	No database hub. Unable to obtain the required full sectoral field dataset covering all regions for assessment purposes.	Develop a comprehensive assets database hub for the whole country.

Area	Gaps in NC3	Post NC3 Specifics	Gaps in NC4	Improvement Plan
		data, SLR, inland-coastal inundation and maps.		
Modelling or Tools for Sectoral Assessment	Gaps not identified in NC3	-	Lack of specific sectoral tools and modelling that link to projected hydroclimate data for vulnerability and impact assessments.	Develop specific sectoral tools and modelling that link to projected hydroclimate data for enhancing and accelerating the vulnerability and impact assessment processes at federal and state levels.
Capacity Building and Awareness	Insufficient capacity to conduct impact assessments in all key sectors.	More agencies have been involved in impact assessments.	Lack of expertise to integrate the projected hydroclimate data with the sectors' vulnerability and impact assessment.	Establish a dedicated team and facilities for developing assessment tools and carry out cross-sectoral assessment exercises; Enhance the capacity in each sector for vulnerability and adaptation assessments.
	Lack of awareness and understanding of the full chain of implications of climate change impacts by key stakeholders in all relevant sectors.	Roadshow / webinars workshops have been conducted to inform stakeholders in all relevant sectors.	Lack of continuous full-scale programmes and activities to create awareness and understanding the full chain of climate change implications conducted at	Develop continuous full scale climate vulnerability and adaptation programs.

Area	Gaps in NC3	Post NC3 Specifics	Gaps in NC4	Improvement Plan
			state/local governmental level.	

4.11.1 Climate Change Projection

Improvements to the of climate projections would continually be carried out. This would include inputs from six GCMs for dynamic downscaling and 20 GCM outputs for statistical downscaling containing the four Shared Socio-Economic Pathway (SSPs: SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) scenarios in the IPCC's Sixth Assessment Report (AR6). The downscaling would be carried out at 6 km grid resolutions for Malaysia. Hybrid downscaling to higher resolution for the selected urban areas will be carried out.

The outputs from the downscaling projections would be used for improving sectoral vulnerability and adaptation assessments. Based on the new projected hydroclimate data, flood areal extent modelling and map developments would be carried out for at least 37 flood prone river basins that cover about 70.3% of the country's land area. An additional hydrological drought index dry will be developed on top of the meteorological drought index to better reflect the consequences of dry spells. Land surface hydrological modelling for producing projected river flow at specific reservoirs / dams will also be enhanced.

4.11.2 Sea Level Rise and Coastal Inundation Projections

The assessment of the coastal vulnerability to SLR requires high accuracy digital elevation model (DEM) data, nearshore and estuaries bathymetric data, which are expensive to acquire. The high-resolution numerical model, which is used to assess and identify the potential coastal inundation due to the projected sea level rise, is under way.

The trend of observed SLR will be evaluated by compiling the long-term satellite altimetry data. This trend is useful to examine the outside factors such as ENSO that may influence the future sea level assessment. Furthermore, dynamical downscaling for SLR will be carried out for selected CMIP6 climate models. Coastal flood inundation and saltwater intrusion simulations using TWO dimensional (2D) numerical coastal hydrodynamic model will then be carried out. In addition, sea surface temperature projection will also be carried out based on the SSP scenarios in AR6. The outputs can be compared using the available reanalysis data provided by the global agencies.

4.11.3 Water and Coastal Resources Sector

There are indeed uncertainties on the assessment of climate change impacts on flood prone areas due to unavailable future land use information. Current flood protection and adaptation measures are insufficient to provide total flood solutions due to climate change impact. The climate change factors (CCF) needs to be fully incorporated into the design and construction of water structures and projects.

For the coastal inundation issue due to SLR, the ISMP studies have not been fully conducted at all the coastal regions in the country. There are also not enough studies and insufficient assessment on saltwater intrusion into the groundwater aquifers in the coastal areas. Extensive hazard study needs to be carried out.

Adaptation projects and programs against climate change vulnerability are still sectoral orientation. There is uncertainty on the effectiveness of these assessments and adaptations when taking into account inter-sector considerations. It is suggested to carry out full chain impact assessment to incorporate embedded inter-sector issues.

4.11.4 Agriculture and Food Security Sector

Rice

In order to further understand the effects of climate change on rice production, crop modelings such as continuous crop development models that integrate physiological growth process model, water consumption and fertilizer consumed, yield prediction, etc., has been carried out for the granary areas. However, there is also a need to extend the efforts to the non-granary areas.

Further study to evaluate crop establishment techniques and varietal performance under extreme climate conditions is needed to further improve the production of rice. Technological adaptation to climate change is also important to deal with the climatic problems in the long run.

Early warning system for pest and disease incidence detection due to changes in weather patterns and extreme weather events; soil remediation improvement due to seawater intrusion and floods, are among the remedies of climate change impacts that are needed to be implemented. In addition, the effect of daily night temperature on rice growth is an area of study that needs to be properly determined.

Livestock

Further exploration is necessary on local livestock breed needs, management practices, disease control and climate adaptation towards ensuring sustainability. New land areas suitable for livestock farming and growing of feed crops need to be identified. Local environment suitable for the imported ruminant breeds for bioprospecting purposes also needs to be identified.

Fisheries and Aquaculture

Changes in sea surface temperature, El Niño-Southern Oscillation (ENSO), sea level, inland water temperatures, rainfall severity and frequency, and water availability, may directly affect the fishery industry and aquaculture productions. Therefore, dedicated weather services including accurate and timely extreme weather prediction should be introduced to provide early warning to farmers and culturists in order to reduce economic loss due to climate change impact.

Oil Palm

Research on development of more productive varieties of oil palm that are resilient to climate stress through the cooperations of industries and stakeholders need to be extended and strengthened. Regional and seasonal climate change modelling approaches, which reveal future patterns of climate scenarios, should be adopted into management practices to enhance the resilience and productivity of oil palm. In addition, the policy on sustainable land use and best management practices should be adhere to avoid unnecessary expansion of oil palm plantations.

Rubber

To enhance the productivity and sustainability, an evaluation of the Genetic by Environment (G x E) influence through assessment of latex production and performance stability of rubber clones across multiple localities needs to be carried out. The assessments of the consequences of environmental changes affecting the development of pests and diseases, and the potential emergence of new diseases, should be continued.

Cocoa

As with the other commodity crops, cocoa-crop development models are needed to further understand the effects of climate change on cocoa. There is a need to intensify the research activities, especially the baseline information, on the impact of climate change to cocoa productions.

4.11.5 Forestry and Biodiversity Sector

Attributing causes of climate change impacts on ecosystems and biodiversity in general is complex. Incomplete information is one of the main knowledge gaps that affect the planning and implementation of climate change adaptation measures for the sector. This is further compounded by the problems in integrating different knowledge systems. Ongoing research and monitoring programmes therefore need to be continued.

The problems that affected the country's marine protected areas are too numerous to be handled by only a few parties. Major paradigm shifts are needed to ensure the sustainability of conservation efforts can be carried out for long-term purposes. One such programme will involve co-management among government-private-civil society by joining hands in tackling some of the basic problems such as solid waste, air pollution, over-harvesting, governance and habitat losses.

Marine turtle conservation efforts in Malaysia are not lacking, but need to be upgraded and coordinated. Community's participation and co-management is a strategic approach for successful conservation interventions. It is therefore envisaged to increase education and awareness of marine turtles and their habitats, conservation needs and threats, amongst the wider public to enhance public participation in conservation activities. Partnership with various stakeholder and business entity can contribute to the sustainable financing mechanism in conserving this species.

The status of all cetacean species is currently unknown due to the lack of historical information and scientific research work has just begun. Primary data collection is still in progress. A proper management plan for marine mammals in Marine Park areas is also needed.

4.11.6 Cities, Built Environment and Infrastructure Sector

Cities and Built Environment

The towns and cities and their built environments continue to face increasing flash floods. The concept of diversion network systems for temporary storage of diverted flood water should be widely accepted and implemented in any future development. Future new towns and cities and built environment plannings should consider the projected future flood areal extent and coastal inundation zonings. Improved early warning systems need to be in place to reduce the losses due to such floods.

As for SLR, the strategy is to prevent further loss of towns and cities, and built environment areas, along the coastal zones. More cautious consideration should be given to future coastal land use and development approval with the increasing inland intrusion of the coastal inundation arising from SLR. The Coastal Erosion Control Programme for the conservation and repairing works along the shorelines, and The ISMP study to assess the risks of coastal erosions on shorelines, being implemented currently should be accelerated to minimise the impact of SLR on the coastal towns and cities and built environments.

Roads

Road projects should take into account the climate change factor (CCF) and exposure to future flood zones and SLR in their design and alignment. The road drainage design shall continue to comply with the Urban Stormwater Management Manual for Malaysia (Manual Saliran Mesra Alam, MSMA).

With respect to dry spells, new strategies which involve improvement of materials such as rut resistant asphalt mixtures, usage of binders that aged slower and usage of asphalt pavement preservation techniques should be introduced. The review of current pavement materials, and evaluation of its robustness with respect to changes in the environment such as temperature and moisture should be conducted before their implementation of new materials. It should also initiate evaluation studies on costs and benefits of modifying the existing materials in order to be more robust.

For the existing and future coastal roads, continuing work on identifying coastal inundated areas, improving designs and maintenance of coastal bunds, rock revetment, beach nourishment and break water structures, for protection of these roads are of utmost importance needed against the impact of SLR. The requirements on buffer zones need to be reviewed and the practise of ecological engineering establishment approaches such as replanting mangrove forest should be prioritised.

Rails

The free board and culverts of railway bridges should be designed incorporating the climate change factor and following the Design Best Practices. The climate change factor should also be incorporated in the design of electrification masts depth and close turf slopes, which follow the Standard Design Specifications and Design Best Practices. Steps to be taken for resilience to SLR inundations on new railways include constructing track and railway facilities at higher elevation. Inland and coastal flood inspections by KTMB's Patrolman or Flying Gang should become a norm in railway operation.

Ports and Jetties

Currently, ports and jetties in Malaysia are facing difficulties in developing the exact quantification of necessary adaptation measures to cope with SLR and coastal floods. The operators of port infrastructures should therefore be provided with projected SLR and coastal inundation maps in order for them to estimate the level of platforms required.

Lack of technology and expertise on coastal erosion prediction and control measures is an obstacle in the sector. Technology that is able to minimize the impact of erosion and siltation on the ports and jetties as a result of higher sea levels and encroaching coastal inundations, should be introduced. More human capacity in coastal erosion modelling should be built.

Airports

It is recommended that the selection of locations of new airports should refer to the projected future flood areal extent maps and coastal inundation maps.

Solid Waste Facilities

In Malaysia, one of the major gaps in solid waste management is that no authority has been given the jurisdiction of handling all the seven types of waste - solid, agricultural, construction, radioactive, mining, sewage and scheduled waste. A centralised authority should be established to comprehensively solve this predicament.

Implementation of the National Solid Waste Management Plan (NSWNP 2016) requires additional allocation for its comprehensive implementation. In addition, the Solid Waste Management and Public Cleansing ACT 2007, which has been adopted by Johor, Melaka, Negeri Sembilan, Pahang, Kedah, Perlis, Kuala Lumpur and Putrajaya, needs to be promoted further to be accepted by the remaining states.

On the technology front, existing sanitary landfills or dumpsites, which are vulnerable to floods and dry spells, should be replaced with more advanced technology such as incinerators that are more resilient to climate change.

Sewerage Facilities

There is no direct impact due to dry spells to sewerage facility. However, via upgrading and rationalization of old and small existing STPs and NPSs through the latest technologies, it is anticipated that the discharge of treated sewage effluent into low river flow during dry spells can occur with less impact. Through establishment of the Water Reuse Policy and Guidelines, the bio effluent can be recycled for non-potable usage to reduce dependency on treated water supply. Constructed wetland is suggested to be used as an additional filtering mechanism before discharging into the river, which is suitable for less habitat size or island.

With respect to SLR, all the new STPs and NPSs shall be mandated to be constructed well above the revised coastal flood level due to inundation, if not all together have the affected STP/NPS relocate to more appropriate places.

Water Supply Facilities

To address the problem of flooded water intake structures of water treatment plants, diversion structures can be proposed to divert the flood water from inundating the intake point. For solving the problem of turbidity of river water due to more frequent extreme weather events such as floods and dry spells under the changing climate, there should be openness towards adopting new advances in water treatment technology.

The Water Demand Management Master Plan completed under the Eleventh Malaysia Plan will enhance sustainable water supply and demand for the future. For urban areas, reducing Non-Revenue Water (NRW) would help to conserve water. The government plans to reduce NRW loss from the 2020 level of 35% to 25% by 2025 and 20% by 2030. The plan also targets the reduction of domestic water consumption from the 2020 level of 205 litres per capita per day (LCD) to 180 LCD by 2025 and 160 LCD by 2030.

Flood Relief Centres

To enable better assessment of the vulnerability of flood relief centres to future floods, a complete national database of these buildings including information on their location and elevation needs to be developed. The existing design standards and guidelines for buildings, especially those serve as flood relief centres need to be reviewed periodically, and the climate change factors should be incorporated. The design standards and guidelines for development in coastal areas need to be enhanced to enable proactive adaptation to sea level rise.

4.11.7 Energy Sector

According to the national standards, the adopted practices above can be enhanced with an integrated approach to the energy sector, both from the structural and non-structural perspective. Non-structural adaptation encompasses management, operational or policy changes, and capacity-building and knowledge management activities. These include modifying design standards for transmission and distribution infrastructure to increase resilience; training or demonstrations of end-use energy efficiency measures; and institutional changes to support mainstreaming consideration of climate change into development and sector strategies. A more rigorous assessment of the impact of climate change on the energy sector needs to be carried out.

Some of the potential flood adaptation measures for hydropower plants include:

- Incorporating climate change factors into new site assessments and adopting new design standards taking into account projected increasing flood risks;
- Incorporating flood protection measures into plant design for protecting the key infrastructures such as intake structure, power house, etc.;

- Increasing dam height and existing spillway discharge capacity wherever permitted structurally;
- Further enhancing flood management plans with precision real-time monitoring and early warning systems;
- Continuing development of integrated reservoir inflow and flood forecasting for the downstream area;
- Enhancing satellite-based monitoring for hydro and thermal power plants;
- Continuing basin-wide management strategies that take into account the full range of downstream environmental and human water uses may prove necessary;
- Restoring and better managing and use at upstream catchments such as afforestation to reduce sedimentation;
- Implementing Risk Informed Decision Making (RIDM) approach to ensure Sustainable Hydropower Dam Safety Management

Some of the potential dry spell adaptation measures for thermal power plants include:

- Installing monitoring systems on source water supplies and develop standard operating procedures for low water conditions;
- Ensuring proper design of cooling water intake and discharge systems;
- Enlarging or retrofitting cooling systems such as water-saving cooling technology to overcome water stress issues;
- Diversifying energy sources and/or the inclusion of supplemental technologies that are less dependent on water for cooling purposes;
- Incorporating climate change factors into site assessments to avoid siting new plants in water-stressed areas;
- Promoting demand management and end-use energy efficiency measures

4.11.8 Public Health Sector

Healthcare Facilities

The increased focus on WASH in healthcare facilities to support The Sustainable Development Goals (SDG) 2030 Agenda, particularly the SDG6 on clean water and sanitation, has raised concerns over the issues and uncertainties related to basic services. The timely development of WASH at healthcare facilities was to track the SDG3 on good health and well-being, which targets to reduce maternal, newborn and child mortality.

However, due to the limitation of data, estimations of WASH in healthcare facilities cannot be conducted nationwide. As a result, infrastructure improvements incorporating climate resilience such as water conservation, waste minimization and low-carbon energy are often overlooked by the stakeholders.

In order to be more robust towards more frequent extreme weather occurrences, specific climate risks of each WASH provision should be identified and prioritized for to further improve these services in healthcare facilities. Broad expertise primarily to address and strengthen WASH at different healthcare facility levels is required.

Vector Borne Diseases

The projections and assessments on climate-health outcomes are rather complex consisting of some degrees of uncertainty in terms of interaction between the cycles of disease with humans, ecosystems and environmental drivers.

Dengue infection, for example, has no particular therapy. There is still no highly effective and safe quadrivalent dengue vaccine to curb dengue transmission. Some current strategies and new approaches to manage the epidemic may include digitalization of dengue tracking approach, virtual monitoring of dengue patients, sustainable vector control activities, and community empowerment and mobilization to create and maintain dengue free environments. Periodical revision of dengue clinical practice guidelines (CPG), training for medical practitioners, and periodical refresher courses for ground staff, have to be continuously carried out and upgraded.

Developing an effective vector control for anopheles' mosquitoes is the biggest challenge in controlling the *knowlesi* malaria. Innovative science and technology on vector control for *knowlesi* malaria is therefore of the highest priority. Improved inter-sectoral collaboration is required in order to develop a more integrated effort to control the spread of the zoonotic malaria. Annual training on the implementation of malaria elimination program is required at all levels to enhance the knowledge and skills in managing malaria. Integrated Vector Management Course, International Malaria Vector Surveillance for Elimination Course and External Competency Assessment for Malaria Microscopists, are among the jointly organised courses organised by the MOH with the WHO, APMEN and ACTMalaria.

FWBD and Leptospirosis

Although the impacts of extreme weather on communicable diseases transmission, especially FWBD and leptospirosis, have been studied in this country, the relationship between climatic factors and the diseases occurrence has yet to be fully understood. There are also some uncertainties in the precise consequences of climate change on the disease's transmission, since other domains are also contributing to the transmission including various ecological drivers (such as land use and urbanisation, pollution and waste management), and socioeconomic factors. All these factors need to be taken into consideration in disease surveillance and environmental health exposure risks reduction.

There is a need to improve the current diagnostic methods and criteria to support early intervention toward better prevention and control of FWBD. Digitalisation of disease surveillance will provide real-time data analysis and acts as an early warning system. Multi-ministries and enhanced societal approaches are required to reduce food poisoning and typhoid cases. Updating current and developing new guidelines on FWBD is also part of the strategies for improvement of surveillance, prevention and control. Ongoing training on outbreak management involving stakeholders at national, state and district level is crucial in FWBD prevention and control activities.

Hotspot mapping of leptospirosis cases in recreational areas by the MOH will enable public to take preventive measures. Community empowerment and mobilization in cleaning high risk areas for rat infestation is also necessary to reduce leptospirosis cases. Revision of leptospirosis guidelines and standard operating procedures is required at regular interval, as part of the standards and strategies for surveillance, prevention and control of leptospirosis. Training for medical practitioners on leptospirosis management is also essential.

Heat Related Illness

Various climate projection models conducted in other countries have indicated a range of health implications of heatwaves. Therefore, local researchers must address the uncertainties in terms of climate effect (such as emission scenarios and variations in urban heat island) and population effect (such as population demographic, population adaptation and acclimatization, and urbanization) raised during the development of temperature-health effect relationship before applying those projections in Malaysia.

The impact of extreme temperatures on health among the Malaysian population still has much to be discovered especially in establishing the association between extreme temperatures and heat-related illness. Furthermore, the primary determinants of cases are also uncertain. Specific research on the vulnerable groups is therefore required. Understanding the association between extreme temperatures, heatwaves and heat-related illness will enable proper assessment of climate change impact, which will help to strengthen the adaptation policies and actions.

The MOH has made progress in terms of capacity building based on the available guidelines in clinical management of heat-related disease and public health response to heatwaves. Areas that require urgent improvement include professional engagement with the community for public education and awareness, data management for evidence-based decision making, and emergency response at all levels of the organization for risk and impact reduction.

CHAPTER 5

5. RESEARCH AND SYSTEMATIC OBSERVATION

5.1 Introduction

Addressing climate change should be based on the best available scientific knowledge and consideration of national circumstances. Malaysia recognised the urgency and has prioritised scientific research, long-term systematic monitoring and data collection for informed policy directions to undertake the necessary response measures.

5.2 Research

Over the past decade, research institutes, universities, NGOs and the private sector had continued with their respective research activities on mitigation and adaptation amidst the dire warnings and bleak scenarios contained in successive assessment reports of the Intergovernmental Panel on Climate Change (IPCC). Funds for this research were primarily from national sources.

5.2.1 Regional Climate Modelling

Climate modelling is an important tool to support the development of science-based adaptation and mitigation measures. This systematic approach will help the country to develop and implement policies and measures that ensure climate-resilient development.

In Malaysia, climate modelling is carried out at the National Water Research Institute of Malaysia (NAHRIM) and the School of Environmental and Natural Resource Sciences of the National University of Malaysia (Universiti Kebangsaan Malaysia, UKM) in collaboration with the Malaysian Meteorological Department (METMalaysia). UKM is leading the lower resolution Southeast Asia regional climate modelling collaboration among ASEAN countries through the SEACLID/CORDEX-SEA programme while NAHRIM leads the higher resolution climate modelling work for the country.

5.2.1.1 South East Asia Climate Downscaling

The Southeast Asia Climate Downscaling (SEACLID) collaboration started in 2010 among seven countries with funding from the Asia-Pacific Network (APN) for Global Change Research. This project was subsequently integrated into the Coordinated Regional Climate Downscaling Experiment (CORDEX), an international regional climate downscaling initiative that is coordinated by the World Climate Research Programme (WCRP) and renamed as SEACLID/CORDEX Southeast Asia. In addition to the core objective of producing and providing a new generation of regional climate downscaling based on fine-scale climate projection for the region, the SEACLID/CORDEX project also serves as a platform to advance climate sciences through capacity-building workshops for young scientists from the region. The platform has also created opportunities for regional scientists to connect to a broader international scientific community.

The first phase of SEACLID/CORDEX-SEA was completed in 2018 with the successful downscaling to 25 km x 25 km resolution from 11 Coupled Model Intercomparison Project Phase 5 (CMIP5) Global Climate Models (GCMs) runs with 7 Regional Climate Models (RCM) using Representative Concentration Pathways (RCP) 4.5 and 8.5. Malaysia's contribution to these runs was based on the RegCM4 model. The project has also successfully established the Southeast Asia Regional Climate Change Information System (SARCCIS), a data portal for sharing CORDEX-SEA data with end-users. SARCCIS hosted by the Ramkhamhaeng University Centre of Regional Climate Change and Renewable Energy (RU-CORE), Bangkok, Thailand is a data node of the Earth System Grid Federation. The CORDEX-SEA climate projection data has enabled 25 peer reviewed papers to be published by the researchers in Southeast Asia of which three were specifically centered on future precipitation variations in Malaysia while another two examined the hydro-meteorological droughts in specific river basins in Malaysia.

The second phase of the project started in 2018 and is centred on downscaling to a higher resolution of 5km x 5km grid. The projection runs for Peninsular Malaysia has been completed while the runs for Sarawak and Sabah are on-going. The research outcomes from these runs would be reported in the next communication.

5.2.1.2 Regional Hydroclimate Modelling for Malaysia

NAHRIM's climate projection for Malaysia utilised the WRF (Weather Research Forecasting) model to dynamically downscale coarse resolution CMIP5 climate projection data of the GCMs to a much finer spatial grid resolution of 6km over Peninsular Malaysia (WRF-PM) and Sabah-Sarawak (WRF-SS) regions. This dynamical downscaling allowed the impact of local topography, local land surface and land use conditions on the local climates of the regions be taken into account. The downscaling was carried out using projections from 5 GCMs for RCP 2.6, 4.5, 6.0 and 8.5.

A total of 16 future climate projections were carried out for the period 2006 to 2100 with historical control runs from 1970 to 2000. Bias corrections were performed for the dynamically downscaled 16 future climate projections. This resulted in 16 x 94-year future climate realisations at a fine resolution over the regions compared to 5 x 30-year downscaled historical realisations from the control runs of the 5 GCMs. The output had been used for the vulnerability and adaptation assessment reported in chapter 4 of this national communication report.

5.2.1.3 City-Scale Modelling

With the concentration of population into urban areas, assessment of changes in the urban climate through city-scale climate projections modelling becomes critical in strengthening the resilience of cities against the impacts of climate change. Equally important is the ability to predict city-scale weather extremes using very fine scale numerical models for effective disaster risk management. As a first step towards this end, UKM's Southeast Asia Disaster Prevention Research Initiative (SEADPRI-UKM) and the Atmosphere Ocean Group of the Department of Applied Mathematics and Theoretical Physics of the University of Cambridge implemented a Disaster Resilient Cities trial project centred on Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur. The project was supported by the Newton-Ungku Omar Fund, under the administration of the Malaysian Industry-Government Group for High Technology (MIGHT) and Innovate-UK.

The project involving 6 UK partners and 10 Malaysian partners across diverse sectors was targeted to improve city-scale weather forecasting and reduce losses associated with natural hazards in Kuala Lumpur. However, the usefulness of such applications would require improvements in the very fine scale prediction model, in particular the surface and boundary layers physics including urban heat island effect and urban landscape canopy. Research work on these aspects is being carried out at the universities.

5.2.2 Coastal Vulnerability

Vulnerabilities of the country's long coastline of 8,840km continue to gain attention as these regions are vital economic zones and population centres.

5.2.2.1 Sea-Level Rise

Sea level along the Malaysian coastline displays a multi-scaled response to local and remote forcing agents. Malaysian tide gauges and neighbouring altimeter records, aggregated monthly, had been analysed to characterise the seasonal to interannual variability in four regions: along coastlines facing the Malacca Strait (Western Malaysian Peninsular), the Sunda Shelf (Eastern Malaysian Peninsular), the South China Sea (Western Sarawak and Sabah) and the Sulu and Celebes Seas (Eastern Sabah).

Understanding the impacts of sea-level rise is crucial in assessing the 11th vulnerability of the country's vast coastal regions. Through funding under the 11th Malaysia Plan, NAHRIM has updated the sea-level rise projection and these results were used for vulnerability assessments presented in Chapter 4 of this report.

The projection of sea level rise took into account future contributions from changes in ocean density and circulation with additional contributions from the loss of mass from glaciers, the surface mass balance and the dynamic response of the Greenland and Antarctic ice sheets and changes in land-water storage as evaluated in the IPCC AR5. The projection was developed using the Coupled Model Intercomparison Project Phase 5 (CMIP5) climate models that were also used in the IPCC AR5 together with models and data representing the contributions from glaciers, the Greenland and Antarctic Ice Sheets, global terrestrial water storage and Glacial Isostatic Adjustment.

The study evaluated value of sea-level rise increment and range, anomaly of uncertainties using multi regression analysis and enhanced analysis of past seasonal and interannual sea-level variability and rise around the coastline of Malaysia.

5.2.2.2 Sea Surface Temperature

During this reporting period, NAHRIM has carried out an analysis of the sea surface temperature trend around South China Sea and adjacent region using the NOAA 0.25°×0.25° Optimum Interpolation Sea Surface Temperature (OISST) dataset based on the simple linear regression of the yearly averaged SST from 1982 to 2021. Most parts of water around Peninsular Malaysia recorded a warming trend of 0.1-0.15°C/decade, except over the southern peninsular where the warming rate is ~0.2°C/decade. The warming rate over Sarawak coastal water is 0.1-0.15°C/decade, whilst that over the Sabah coastal areas is slightly higher at 0.15-0.20°C/decade.

5.2.3 Water Resources

Malaysia is paying close attention to the vulnerability of its water resources to the impacts of climate change. Under the 11th Malaysia Plan, NAHRIM has undertaken several studies through fine-scale modelling to produce projections of the impacts of climate change on the hydrological regime and water resources of Malaysia.

Two primary studies had been completed namely the extension study of the Impact of Climate Change on the Hydrologic Regime and Water Resources of Malaysia (Phase 2) and the Impact of Climate Change on the Hydro-Climate of Malaysia based on IPCC AR5 for Peninsular Malaysia, Sabah and Sarawak. A third study focusing on drought is on-going and would be completed in 2022.

NAHRIM has also developed the Climate Change Adaptation Framework for the water sector focusing on water resources, utilisation and risks associated with climate change which will be instructive in the development of the National Adaptation Plan.

5.2.4 Agriculture

Research in this sector focuses on the vulnerabilities of key crops to the changing rainfall patterns, temperature rise and floodings. Therefore, studies were carried out to discover drought- and flood-tolerant traits of the various crops. In the livestock sub-sector, research efforts were focusing on the development of enteric fermentation country-specific emission factor for the various cattle breed.

5.2.4.1 Oil Palm

In NC3, the effects of rainfall and temperature on growth and yields of oil palm for nearly three decades were reported. A recent canopy scale modelling study on oil palm in peatland demonstrated that palms were exerting significantly greater stomatal control at deeper water table depths (WTD) and the optimum WTD for photosynthesis was found to be between 0.3 and 0.4m below the soil surface. Raising WTD to this level from the industry typical drainage level of 0.6m could increase photosynthetic uptake by 3.6% and reduce soil surface emissions of CO_2 by 11%. Site study further showed that despite being poorly drained compared to other planting blocks at the same plantation, monthly fruit bunch yield was, on average, 14% higher.

5.2.4.2 Rice

Since 2015, Malaysian Agricultural Research and Development Institute (MARDI) through its Paddy and Rice Research Centre and Agrobiodiversity and Environment Research Centre have conducted various studies on varieties that can be grown under drought conditions. These efforts include assessing current varieties as well as developing new ones (with drought-tolerant traits).

Cultivation of rice under drought conditions involves the growing of rice with supplemental irrigation, without the necessity for maximum standing water in the field. Early studies showed that the current rice variety, MARDI Siraj 297, could be cultivated under limited or saturated water conditions. The results showed that maintaining an irrigation system in saturated conditions did not cause significant reduction of the plant physiological performance. The saturated condition was able to sustain similar soil moisture content required by the plants as in flooded conditions.

In addition, studies have also identified a local specialty rice variety, MRQ 76, of having drought-tolerant traits that can be introduced to farmers in non-granary areas that are water stressed.

Under the 12th Malaysia Plan (2021-2025), the research will be further strengthened through pilot scale studies and field assessments in areas prone to the impacts of climate change.

5.2.4.3 Rubber

A model had been developed to assess the impacts of climate change on rubber cultivation. The model took into account particularly on the rainfall patterns and temperature rise on the maturity on the growth and latex production. The result from this study had been used to develop adaptation strategies for the sector. In addition, research to develop climate resilient clones is ongoing.

5.2.4.4 Cocoa

Research work was undertaken by the Malaysian Cocoa Board (MCB) on the impacts of climate change on the crop yield. Twenty-four commercial cocoa clones were screened for their drought and flood tolerance traits and classified according to their respective tolerant levels. Further field test would be required to refine the findings.

An 11-year observation of ant colonies in cocoa plantations against temperature and rainfall patterns were analysed. The result indicated reduction in ant colonies with increase in temperature. Ants are important to control cocoa pod borers outbreak in the plantations.

5.2.4.5 Livestock

Under a technical assistance from the Global Research Alliance on Agricultural Greenhouse Gases (GRA) and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), a workshop has been conducted by NZAGRC researcher in Malaysia with an objective to improve the country’s inventory reporting for ruminant livestock subsector, through implementation of IPCC tier-2 methodology in the enteric methane emission estimates. Initially, a set of country-specific emission factors were developed based on Brakmas, which is a local beef cattle breed. The emission factors developed had been used for the GHG Inventory reporting. Work is on-going to develop the enteric fermentation emission factor for Elite KK, another local beef cattle breed.

5.2.5 Forestry

A long-term Free-Air Carbon Dioxide Enrichment (FACE) research is being undertaken to assess the impacts of elevated CO_2 in an inland forest (Tekam Permanent Reserved Forest, Jerantut, Pahang). This study will quantify the effect of elevated CO_2 on the productivity of lowland forest which is managed under the Sustainable Forest Management. Outputs from this study will be used to develop adaptation measures for the forestry sector.

5.2.6 Tropical Peatland

Disturbance to peatlands which are critical reservoir of greenhouse gases has gained huge international attention in the fight against climate change. In 2016, the Sarawak Tropical Peat Research Institute (TROPI) was upgraded from the Tropical Peat Research Laboratory (TPRL) to advance research in tropical peatland. Research work at TROPI is centred on GHG inventory emission inventory from peatlands and forests, carbon stock, carbon dynamic, pedo-hydrology, soil and water chemistry, plant nutrition and soil fertility, forest tree inventory, environmental microbiology and plant pathology.

At TROPI, GHGs flux are measured using two common methods, the chamber-based (manual and automated chambers) and the eddy covariance method. Manual chamber method is used to measure the soil GHG fluxes, and TROPI has been using this method since the establishment of TPRL in 2008 to measure soil CO_2, CH_4 and N_2O fluxes. Automated chamber method is now being used to measure soil CO_2 and CH_4 fluxes continuously since 2014.

TROPI uses the eddy-covariance technique, a micrometeorological technique for direct measurements of gas exchange between the surface and the atmosphere. In 2010, eddy covariance flux towers were set up in three different ecosystems in Sarawak: (a) a peat swamp forest located at Maludam National Park, (b) a secondary peat swamp forest and (c) an oil palm plantation. Measurements are made above the tree canopy at 41m height in both peat swamp forest and secondary peat swamp forest, while measurements are made at 21m height for oil palm plantation. In 2017, the secondary peat swamp forest was converted into an oil palm plantation. Thus, the measurement height was changed from 41m to 21m. The CO_2 fluxes, sensible and latent heat fluxes, and meteorological measurements have been measured since 2011, while the CH_4 fluxes measurement started in September 2012, in collaboration with the Hokkaido University and the National Institute for Environmental Studies (NIES), Japan.

5.2.7 Public Health

Climate change can exacerbate existing health issues or create new public health challenges through a variety of pathways from extreme weather episodes to spread of certain diseases. In recent years, the Institute for Medical Research (IMR) which is the bio-medical research wing of the Ministry of Health Malaysia (MOH) has kept up with research on climate-related health threats.

Evidence from local research on climate change impacts to human health has increased considerably over the past few years. However, focus on certain disease burden and the linkages with climate change need to be explored further where international collaboration is essential. Health Research priorities under the 12th Malaysia Plan (2021 – 2025) has outlined two focus areas: climate change and climate-sensitive diseases; and health vulnerability and adaptation assessment including during extreme weather events.

5.2.7.1 Vector-borne Disease

Dengue

Malaysia has conducted extensive studies in various aspects of dengue infection. These include epidemiological surveillance, laboratory diagnostic, clinical management, and entomological surveillance studies.

Research of dengue outbreak and its relationship with land use in the most populated state of Selangor were carried out since 2014. The land use effect mapping using Local Moran I analysis was used to study agriculture, stagnant water bodies, housing, industry, open land and drainage in four districts. The study was able to identify location of hotspots for dengue fever in relation to each type of land use.

In addition, Artificial Neural Networks architecture (ANNs) was applied for prediction of number of dengue cases per week in the district of Klang using previous week reading of weekly mean rainfall, mean temperature, mean relative humidity and infection cases. The results serve as early warning, pin-pointing to the most likely vectors breeding sites.

The ANN prediction model was also used to predict weekly dengue cases, patients' serology and patients' dengue fever type with input of meteorological and clinical parameters with considerable accuracy which contribute towards better understanding of outbreaks and development of prevention and control measures.

Projection of dengue transmissions with climate as a driving force based on the IPCC AR5 Representative Concentration Pathways (RCPs) was made for two districts in Peninsular Malaysia - Petaling in Selangor and Johor Baru in Johor – for the period of 1970 to 2100. The projected dengue cases in the district of Petaling following the RCP8.5 scenario is four-fold of that projected under the RCP4.5 scenario meanwhile the district of Johor Baru showed less sensitivity to the magnitude of the temperature change. This study would provide the basis for policy makers to develop adaptation strategies in management of dengue fever to cope with the impacts of climate change.

Entomological research on the wAlbB strain of Wolbachia (a bacterial endosymbiont of arthropods) provides promising option as a tool for dengue control, particularly in very hot climates. Releases of *Aedes aegypti* mosquitoes carrying the wAlbB strain were carried out in six diverse sites in Greater Kuala Lumpur with high endemic dengue transmission. The strain that could block dengue virus transmission into population of the primary vector mosquito, *Ae. Aegypti* was successfully established and maintained at very high population frequency at some sites or persisted with additional releases. Based on passive case monitoring, reduced human dengue incidence was observed in the release sites when compared to control sites. Several articles on this subject have been published. However, the research is currently ongoing in order to provide evidence-based decision-making in vector control.

Malaria

Studies on *Plasmodium knowlesi*, the emerging species for malaria in Malaysia has applied geographical data and ANN to forecast malaria cases. Significant environmental factors – elevation, water bodies, rainfall, land surface temperature and normalised difference vegetation indices - were used as input for the ANN analysis.

Infection by this species contributes to almost half of all malaria cases and deaths particularly in the Borneo region. The malaria susceptibility index and zoning analysis revealed that regions near Sabah's Crocker Range and in the eastern part of Sabah were more vulnerable to *P. knowlesi* infections.

A study on the epidemiology of malaria in Malaysia from 2000 to 2018 highlighted the threat posed by zoonotic malaria to the National Malaria Elimination Strategic Plan. Although Malaysia did not record any indigenous cases of malaria caused by human malaria parasites for the first time in 2018, there was nonetheless an increase in *P. knowlesi* infections that year with a total of 4,141 cases reported.

While *P. knowlesi* infection can be attributed to a variety of factors, more than half of cases were linked to agriculture and plantation activities, with a large proportion of the remaining cases linked to forest-related activities.

5.2.7.2 Food and Water-borne Disease

Research on food and waterborne diseases in Malaysia has been conducted to evaluate the association of meteorological parameters and post-extreme weather events (such as flood) to the outbreak trends. The hot and humid climate along with poor sanitation and inadequate water supply during flooding, creates an opportunity for the transmission of food and waterborne bacteria leading to a public health risk. The association between temperature and precipitation with food and water-borne diseases were also documented by a study which found that the odds of having cholera cases increases by a factor of 3.5 for every 1˚C increase in temperature.

Although prevalence of diarrheal diseases has reduced in the past decades, increased rain and flooding have increased the occurrence of the diseases. This was shown following the major flood in Kelantan in 2014, in which 14.2% of confirmed typhoid fever were found to be related with the event. The collapse of infrastructures following the massive flood caused disruption to hygiene and sanitation services, creating an ideal environment for typhoid fever transmission. Additionally, a significant increase in enteric pathogen isolates particularly *Salmonella sp* were registered during the post-flood period.

5.2.7.3 Leptospirosis

Leptospirosis is an emerging disease, especially in countries with a tropical climate such as Malaysia. This was attributed to the large number of reservoir animals, suitable humid and moist environment for proliferation as well as abundant forest resources.

Current studies suggested the influence of extreme weather and climate change in this zoonotic disease. There are increase risk of human exposure as the frequency of flooding increased in recent years. In East Coast of Peninsular Malaysia, leptospirosis showed an increased in reported cases following a massive flooding event in 2014.

Understanding the spatial distribution and associated factors of leptospirosis can help improve future disease outbreak management in relation to flood events, including to help in identify localities with a strong environmental or socio-demographical determinants for leptospirosis transmission.

Current studies showed positive association of leptospirosis cases with heavy rainfall and flooding in Malaysia. With projected precipitation and flooding in increasing frequency and greater intensity, these may potentially drive the surge in leptospirosis incidence and outbreaks. Further research is required to understand the environmental drivers and climate change hazard risks viz-a-viz population dynamics towards strengthening emergency preparedness and adaptive capacity.

5.2.7.4 Heat-Related Illness

The future increase of temperature as a result of climate change combined with the humidity profile in Malaysia is expected to threaten the population's health and economy. Impact of extreme temperature and heatwave to human health can be either direct heat related illness or indirect health impacts such as cardiovascular and psychological impact.

Studies on heat related illness have been made deploying various methodologies from basic epidemiological approach using survey to modelling and other statistical downscaling cluster approach survey.

However, there are some complexities to determine health impacts of extreme high temperature particularly in urban micro-climate. Urban heat island effects and air pollution could compound the effects of global warming, making the urban population, a vulnerable group. People with respiratory diseases, the elderly, and women were the most vulnerable groups when it came to the effects of extremely high temperatures.

Cases of heat-related illness have been reported in Malaysia which showed the severity of the illness. However, there was limited research on the prevalence of heat-related illness among the general population. Most of the studies were done on environmental heat exposure at work such as among traffic police, solid waste management workers, and farmers which showed a significant occurrence of heat related illness. Besides common symptoms of heat related illness such as heat exhaustion and heat syncope, exploration of other symptoms such as psychosomatic pain, psychological anxiety, and somatization-related symptoms have shown to be significantly associated with heat stress in recent studies conducted in Malaysia.

More research needs to be conducted to examine all aspects of the impact of heat and extreme temperature in Malaysia. Studies on vulnerabilities and adaptative capacity especially among vulnerable and sensitive populations are still lacking.

5.2.7.5 Non-communicable Respiratory Diseases

Studies in this area were conducted on the health effects of transboundary pollutants as a result of regional forest fires during prolonged dry months which had become a recurring phenomenon since the 1980s, with the worst episode in 1997. Significant increase in natural and respiratory mortality were registered among Klang Valley residents as a result of exposure to hazy days, with higher risks of respiratory mortality than natural mortality.

5.2.8 Energy

The key research entities of the energy sector have made some significant achievements in the deployment of renewable energy technologies particularly in the field of solar and biogas energy. Improvements were also made on carbon capture and utilisation technologies to decarbonise coal plants operation.

5.2.8.1 Renewable Energy Research, Development and Deployment

The TNB Research Sdn. Bhd. (TNBR) and SIRIM Bhd. (SIRIM) has continued their respective research efforts in the development of renewable energy technologies to suit local conditions. Several innovative technologies were successfully developed and deployed.

Palm-based Bio-energy

Research to harness the biogas potential in the oil palm sector has gained momentum and significant outcome. SIRIM has developed a 200 mmbtu/day bio-compressed natural gas production plant in Tawau, Sabah to demonstrate the feasibility of utilisation of Compressed Bio-as (CBG) from palm oil mill effluent for land transport and industry usage. Palm oil millers in Sabah have started to use compressed bio-methane gas in their trucks. The construction of the first CBG pipeline in Johor with a capacity of 1,000 mmbtu/day was started in late 2020 and is scheduled for completion by end of 2022. The barrier to a smooth supply chain of CBG is also being overcame with the development of Type 4 Light Weight Composite Cylinder in addressing the storage and distribution challenge.

Meanwhile, TNBR has developed a Non-Thermal Plasma (NTP) system to reform biogas. Three different conditions were developed namely, (i) for biogas with low calorific value the NTP reforms the biogas into higher hydrocarbons to provide enough energy for power generation; (ii) separation and capturing of CO_2 in the biogas that can be used for co-combustion with CH_4 to increase heat generation; and (iii) to reform the biogas by dissociating CO_2 to CO, combining it with radicals from dissociated CH_4, to produce value-added chemicals such as methanol, which can be used as liquid fuel for vehicles.

Solar Thermal and Its Application

SIRIM has carried out various Solar Thermal Application Projects in various industries such as poultry farming, food and beverages, downstream agricultural productions and the hospitality sector. The application in solar water heater which is one of the energy-guzzling electrical appliances that is widely used throughout the country has a huge potential to switch the electricity dependence from fossil fuel to solar energy.

SIRIM is also looking at the potential of Solar Thermal System for power generation by using Concentrated Solar Power (CSP). In supporting development in this field, SIRIM has collaborated with UNIDO to develop the UNIDO/SIRIM Standard which provides requirements, specifications, guidelines or characteristics that can be used to ensure that materials, products, processes and services are fit for their purpose.

Floating Solar Photovoltaic (FSPV) System

To address the challenge of land constraint on the deployment of solar energy, TNBR has conducted feasibility studies on floating solar farm. This project aimed to determine the feasibility of constructing a grid-connected photovoltaic system on water surfaces and assess the economic value. The research project found that the energy generation of the FSPV is higher than solar PV installation on the ground due to the cooling effects of the water body. The actual module temperatures were significantly less than the average values of ground-mounted solar PV systems. In conjunction with the findings, the project developed a 108 kWp FSPV system at the Sg. Labu Off-River Storage (ORS) in the state of Selangor. Annually, the 108kW grid-connected FSPV system will be able to produce 137.97 MWh of energy. Experience from this project would enable the scaling-up of the FSPV system to other Off-River Storage (ORS) reservoirs.

A second test site at disused coal ash ponds yielded favourable results. Further experiments are being carried out on hydro dam reservoirs and offshore waters.

Hydro Turbine System Innovation

TNBR has made significant improvement on the impulse hydro turbine system using the new innovation impulse turbine bucket. Innovation was also made on the nozzles of the conventional Pelton turbine. The innovation was patented as Bahari Impulse Hydro Turbine (BIHT). The efficient, highly flexible and cost-saving design of BIHT could generate electricity from 5kW to 600MW, thus increasing the potential for the development of run-of-the-river hydro-electric plants throughout the country especially in remote areas.

5.2.8.2 Decarbonisation of Coal Plants

Since NC3, TNBR has continued its experiment and research on carbon capture and utilization (CCU) technologies at existing power plants. Two projects at the CCU Research Station in TNB Janamanjung power plant have yielded strong potential for adoption and scaling-up.

Microalgae with Enhanced CO_2 Fixation

A new nutritional mode which led to higher growth of a local microalgae species was discovered thus greatly improved the fixation rate of carbon dioxide (CO_2) of the organism. This is the first pilot Algae Bio-CCU technology in Malaysia tested with actual flue gas from a live coal-fired power plant.

Amine-Based Technology for Carbon Capture and Utilization (CCU)

The ideal solvent was discovered for the amine-based gas cleaning system that has vastly improved the absorption rate of CO_2. The technology and solvent aided in reducing the reboiler duty, temperature and related operational costs.

5.2.9 Greening of Industrial Park

The Ministry of Investment, Trade and Industry (MITI) through its agency, SIRIM has initiated a research program to streamline the development of Eco-Industrial Park (EIP). The primary objective of the study is to facilitate the transformation of existing industrial parks (IPs) towards Eco-Industrial Parks (EIPs) based on the international best practices as documented by World Bank Group, UNIDO and GIZ. Malaysia has adopted the definition of EIP as *"A community of manufacturing and service businesses located together on a common property. Member of businesses seek enhanced environmental, economic and social performance through collaboration in managing environmental and resource issue."*

The adoption of the eco-industrial parks concept which embodies the circular economy model will be made a pre-requisite for the development of new industrial parks. Existing industrial parks will also be encouraged to adopt the model, by promoting collaboration among tenants in these parks in managing resources and environmental issues efficiently. Industry players will be required to adopt the Environment, Social and Governance (ESG) elements in their business practices. An industrial standard is currently being developed to establish the prerequisites and performance indicators/criteria of EIP which are based on these ESG principles.

The research program will assist the park managements and tenant companies to benchmark their performances against a set of EIP criteria; assessing the tenant companies for the baseline efficiency on the resource utilization, identify industrial symbiosis opportunities which will then be turned into business model and finally acknowledging some of the core industrial parks as potential EIP; deserving technical and financial assistance to enhance its productivity and better promotion package to encourage sustainable investment into the EIP.

5.3 Systematic Observation

Monitoring of climate change and assessment of its impacts are conducted by several frontline technical governmental agencies and departments. Meteorological parameters are monitored by two key agencies, the Malaysian Meteorological Department (METMalaysia) and the Department of Irrigation and Drainage (DID).

METMalaysia gathers meteorological data from its nationwide network of weather stations while DID collects rainfall data and monitor water level of river basins for its hydrological observation. Observational networks and the sensors used have evolved since their early days in line with the technological changes.

Other agencies such as the Slope Engineering Division of Malaysian Public Works Department (PWD) and Projek Lebuhraya Utara-Selatan (PLUS), the concessionaire of the north-south axis highway of Peninsular Malaysia also carried out rainfall observations at hilly region and along the tolled highways respectively.

Monitoring in the biodiversity and natural ecosystem are reported through the national reporting to the Convention on Biological Diversity and the Forest Resources Assessment (FRA) which focuses on the baseline status and trends. The assessments contained in these reports have indirect information on climate change impacts.

5.3.1 Climate Observation

Malaysia continues to operate a network of weather, climate and global atmospheric watch stations for systematic and long-term data collection.

i. Weather and Climate Observation Stations

The METMalaysia operates a network of 43 principal meteorological stations, most of which are located at the airports. The Department operates a further 200 automatic auxiliary weather stations, 34 climatological stations and 150 rainfall stations which are located within the compound of public hospitals and clinics, government buildings at states and district levels, schools and plantations. These weather stations measure a large variety of different meteorological parameters: air temperature; atmospheric pressure; rainfall; wind speed and direction, humidity; sunshine hour and solar radiation. Changes of the climate in Malaysia are assessed through long-term records of these established efforts. A 30-year average of a station’s weather observations is traditionally used to determine the local climate.

ii. Upper Air Stations

The department also operates eight upper air observation stations. Each station releases two meteorological sonders per day in order to get the atmospheric vertical profile information, such as the wind condition, air temperature and air humidity up to 50 km above the ground.

iii. Global Atmospheric Watch (GAW) Stations

As a member of the World Meteorological Organisation (WMO), Malaysia participates in the world body's Global Atmospheric Watch (GAW) programme since 1989. Under this programme, Malaysia has established a network of GAW monitoring stations that carries out systematic monitoring of atmospheric constituents to study and understand the regional issues on transboundary haze, acid deposition, climate variability, climate change and stratospheric ozone depletion.

The country currently operates a global GAW station at Danum Valley, Sabah and three regional GAW stations at:

- Tanah Rata, Cameron Highland;
- METMalaysia Headquarters at Petaling Jaya, Selangor; and
- Bachok, Kelantan

The Regional GAW station at Bachok was set up in 2014 in collaboration with the University of Malaya (UM), the University of East Anglia and the University of Cambridge and is operated by the UM's Institute of Ocean and Earth Sciences. The station's location over the coast of eastern Peninsular Malaysia allows studies of land sea atmospheric circulation, ocean air interactions and coastal uplifts. In collaboration with the National Environmental Research Council of the United Kingdom, this station is also a part of the Global Methane Measurement Network since 2016.

The types of observation made at the GAW stations are shown in Table 5.1 below.

Table 5.1: Monitoring Activities of GAW Stations in Malaysia

Focal Areas	Danum Valley	Cameron Highlands	Petaling Jaya	Bachok	Gunung Raya, Langkawi	Gunung Brinchang, Cameron Highlands	Bukit Sebangkoi, Sarawak
1. Aerosols							
• **Aerosol Load**	✓	✓	✓	✓			
• **Back Scattering Coefficient**	✓						
• **Absorption Coefficient**	✓						
• **Aerosol Optical Depth**	✓		✓				
2. Greenhouse Gases							
• **Carbon Dioxide**	✓			✓	✓	✓	✓
• **Methane**	✓			✓	✓	✓	✓
• **Nitrous Oxide**	✓			✓			
• **Sulphur Hexafluoride**	✓						
3. Reactive Gases							
• **Carbon Monoxide**	✓	✓		✓	✓	✓	✓
• **Nitrogen Oxides**		✓		✓			
• **Sulphur Dioxide**	✓	✓	✓	✓			

Focal Areas	Danum Valley	Cameron Highlands	Petaling Jaya	Bachok	Gunung Raya, Langkawi	Gunung Brinchang, Cameron Highlands	Bukit Sebangkoi, Sarawak
• Hydrogen	✓				✓	✓	✓
4. Ozone							
• Surface Ozone	✓	✓					
• Total Column Ozone			✓				
5. UV Radiation			✓				
6. Precipitation Chemistry	✓	✓	✓	✓			

Malaysia also operates a vertical profile ozone monitoring station at Sepang, Selangor where ozonesondes are released twice monthly. This data is shared with the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) and the Southern Hemisphere Additional Ozonesondes (SHADOZ) network.

5.3.2 Hydrological Observation and Flood Warning System

The DID started implementing telemetric water level and rainfall observations in the major river basins following the 1971 big flood. These programmes have since been expanded to smaller rivers and as of 2021, a total of 99 river water level and 626 rainfall stations and 455 combine stations (rainfall and water level) along the river basins had been installed.

DID has also installed flood siren systems in some of the smaller river basins in the urban areas where flash flood occurs frequently. In these river basins there is little lead time available for effective warning. Hence flood warnings sirens are automatically trigger to warn the residents of an impending flood once the water level reaches a critical point.

Since 1980, flood warning notice boards have also been erected in the major river systems. There are three categories of warning board which are for monsoon flood, flash flood and the combination flood.

5.3.3 Drought Information & Warning System

DID initiated the drought monitoring programme since early 2001 to provide drought information. The early warning system was established following the 1998 drought incident which affected a large number of residents in the Klang Valley. A web portal was developed with the aim to communicate drought information to relevant stakeholders to trigger early preparation for drought events.

As of 2022, the programme is supported by 17 dam level stations, 55 river water level stations at gauging site and 183 rainfall stations which provides information about the real time situation on storage in dam and river flows as well as rainfall data.

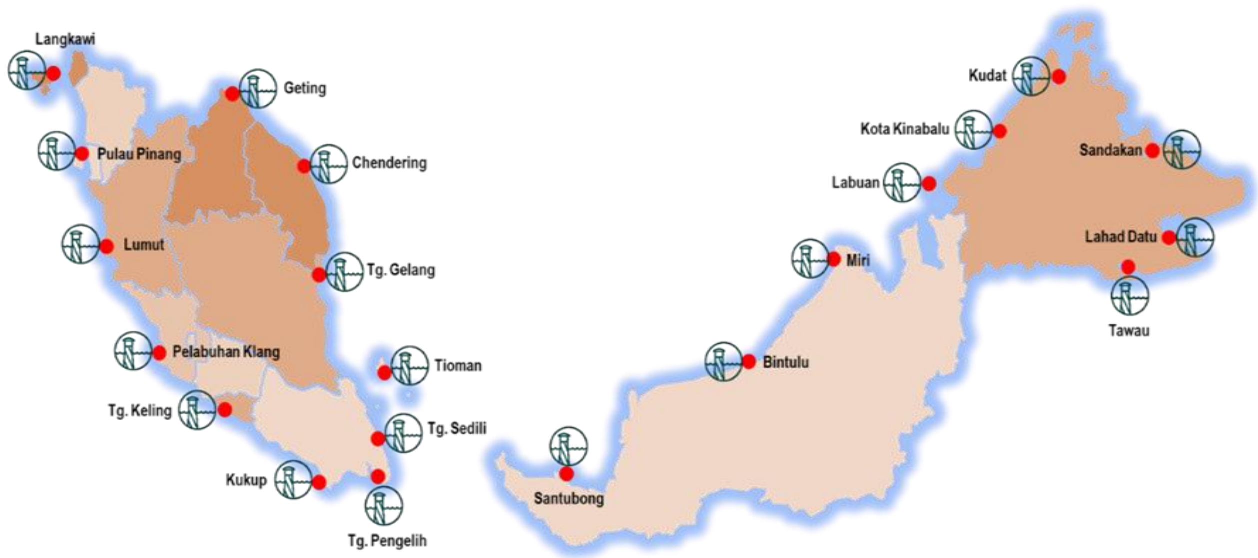
5.3.4 Sea-Level Monitoring

Sea level rise is monitored by the Department of Survey and Mapping Malaysia (JUPEM) which began as the Tidal Observation Project dating back to the Fourth Malaysia Plan (1981-1985).

To date, a total of 21 tide gauge stations, 12 in Peninsular Malaysia, Sabah (5) Sarawak (3) and one station in Labuan forms the Tidal Observation Network to provide the precise mean sea level values for the establishment of the new Precise Levelling Network for Peninsular Malaysia where all the tide gauges stations are connected to each other through a network of precise levelling lines.

With the recorded tidal data, JUPEM is able to obtain sea level rise trend through time series analysis from the date of establishment of the tide gauge station.

Figure 5.1: Location of JUPEM's Tide Gauge Station in Malaysia



5.3.5 Forestry

Forestry authorities has kept up with long-term monitoring efforts of the health and function of the various forest ecosystems in the country which would provide invaluable insights into the impacts of climate change. Such long-term data collection is vital towards the development of both mitigation and adaptation measures.

5.3.5.1 National Forest Inventory

The Forestry Department of Peninsular Malaysia conducts a 10-year-interval forest inventory in Peninsular Malaysia since 1972. Efforts are being made to implement similar programme in Sabah and Sarawak in a consistent manner and to align the exercise across all three geographical regions. A Malaysian Forest Inventory Report will be produced by 2025.

5.3.5.2 Eddy Covariance Flux Measurement

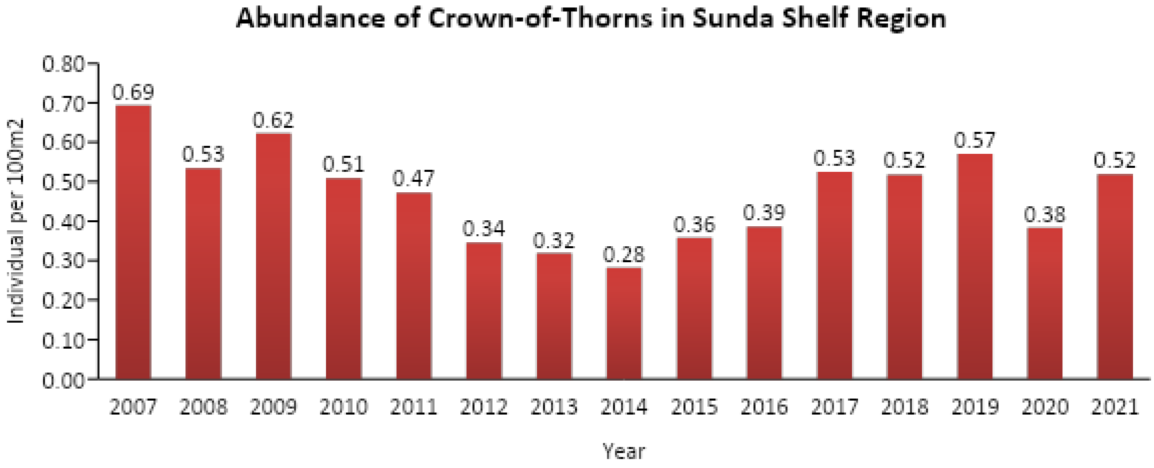
Eddy covariance techniques is used for long-term quantification of gas exchange rates by directly measuring turbulent flux in the near surface atmosphere above an ecosystem and thus also above the soil surface. It is used to estimate the exchange of carbon dioxide, heat and water vapour as well as methane and other trace gases. The eddy covariance flux measurements are conducted in forests and oil palm plantations. The monitoring station in the inland forest at Pasoh started in 1998. In year 2010, Sarawak Tropical Peat Research Institute (STROPI) set-up three eddy Covariance flux towers in three different ecosystems in Sarawak: (i) a peat swamp forest located at Maludam National Park, (ii) a secondary peat swamp forest and (iii) an oil palm plantation. The CO_2 fluxes, sensible and latent heat fluxes, and meteorological measurement in all sites has been done using eddy-covariance method since 2011 while the CH_4 fluxes measurement was started in September 2012.

5.3.6 Coral Reefs Monitoring

Coral reefs are an important ecological and economic resource in Malaysia, providing a range of valuable ecosystem services to many people. Based on Reef Check Malaysia's coral reef monitoring data collected from over 150 permanent survey sites from 2007 to 2021, Malaysia's coral reefs are in 'Fair' condition, recording an average 44.44% live coral cover (hard coral cover + soft coral cover) over the past 15 years. Abundance of fish and invertebrate indicators remains generally low suggesting either historical or on-going fishing pressure. Numerous indicators of disturbance (recently killed coral, coral rubble and silt) and pollution (nutrient indicator algae and sponge) highlight ongoing concerns about the trajectory of coral reefs health. Indicators of disturbance are mainly recorded in North Borneo region (Sabah) while indicators of pollution are mainly recorded in Sunda Shelf region (East coast of Peninsular Malaysia and Sarawak).

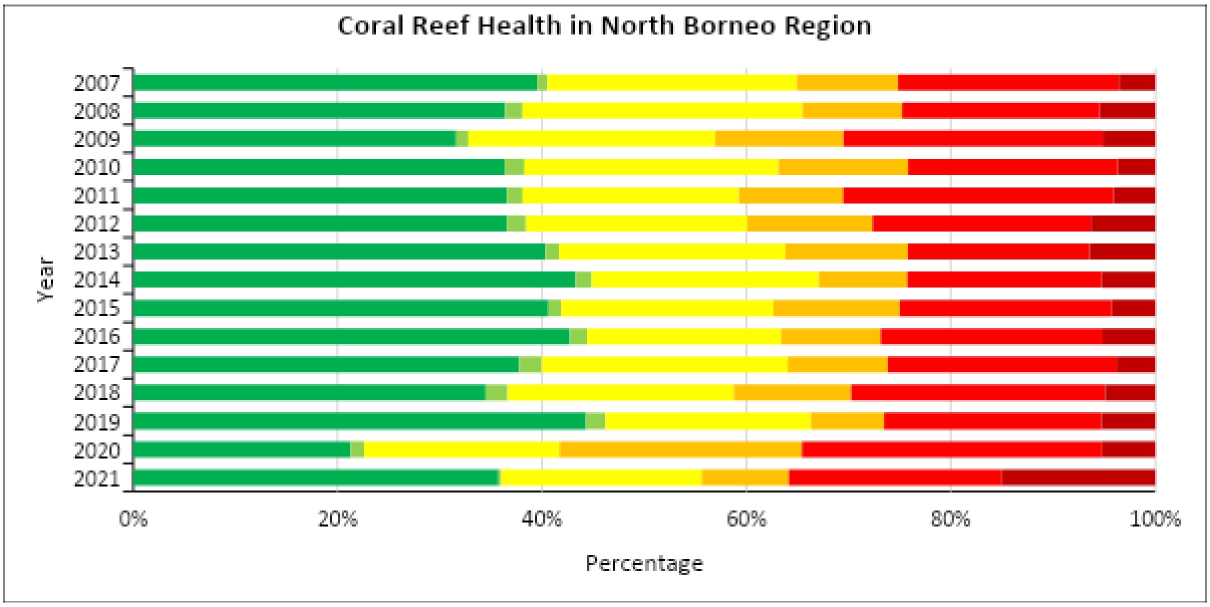
The Crown-of-Thorns (CoT) starfish is an important predator of coral. While it does not appear to be a threat in most places, there are some sites where CoT abundance is an issue that needs attention, especially in Sunda Shelf region. Every year except in 2014, the abundance of crown-of-thorns starfish in Sunda Shelf region is above what a healthy coral reef can support (0.2-0.3 individual per $100m^2$).

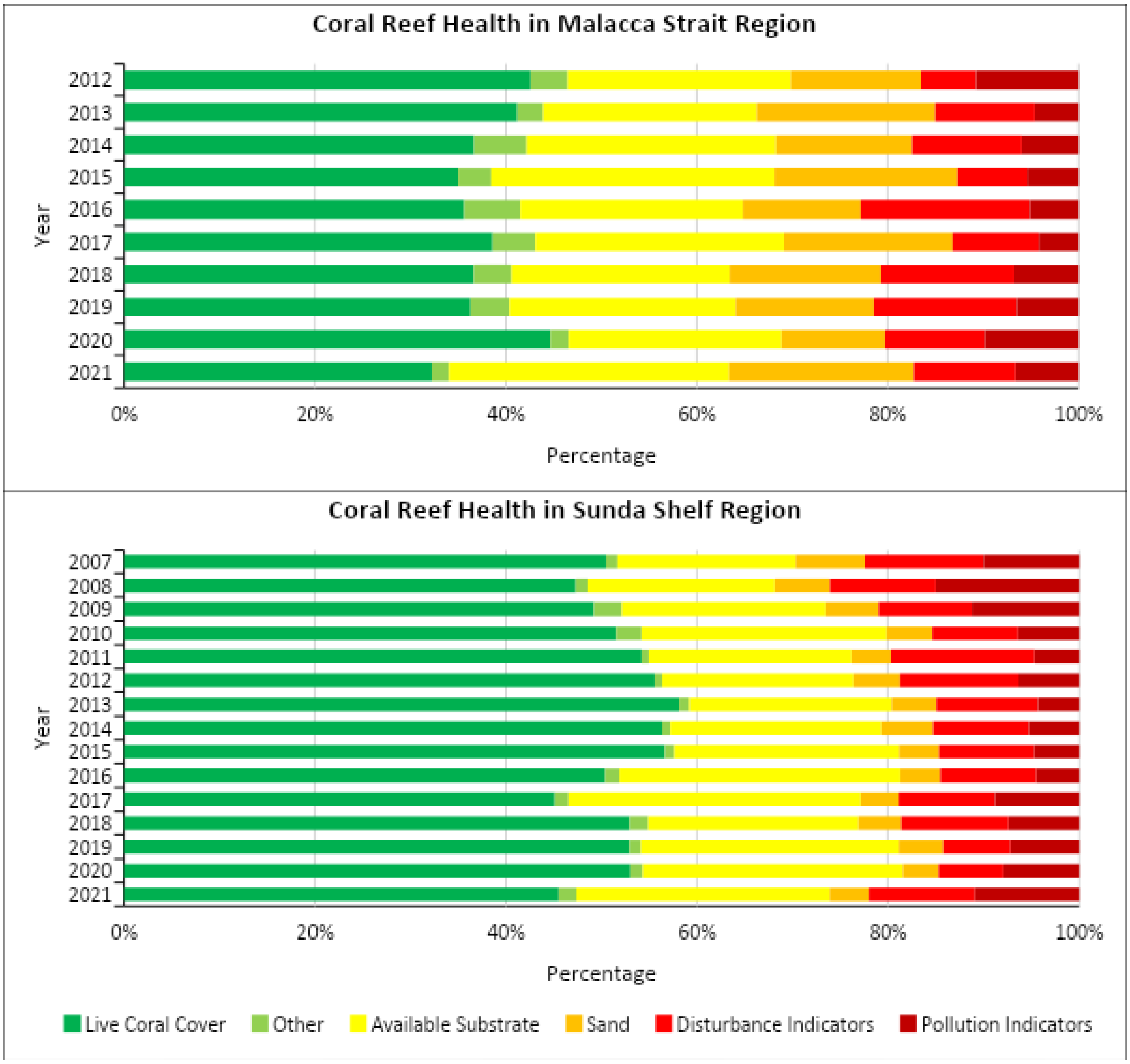
Figure 5.2: Abundance of Crown-of-Thorns in Sunda Shelf Region



Narrowing it down to eco-regions (an area of relatively identical species composition, clearly distinct from adjacent regions), the health of coral reefs in the North Borneo and Malacca Strait regions has remained more or less the same over the past 15 years. From 2018 onwards, coral reefs in the Malacca Strait region show improvement as reduced disturbance indicators allow coral reefs to improve. The health of coral reefs in Sunda Shelf region on the other hand shows some variation. From 2015 to 2020, coral reefs in Sunda Shelf have deteriorated. In 2021, the coral reefs show improvement. The improvement is mainly attributed to recovery of coral reefs in Terengganu following damage caused by Tropical Storm Pabuk in January 2019. Available substrate for coral recruits to attach to is high, indicating possible chance of further coral reefs recovery if human impacts and crown-of-thorns starfish populations are dealt with.

Figure 5.3 Coral Reef Health in three main eco-regions





Climate-related impacts to coral reefs are increasingly evident during reef surveys. The three main impacts to coral reefs of climate change are:

i. Bleaching: higher than normal water temperature causes corals to expel microscopic algae that usually live in their tissues, algae that are an important source of nutrients for the coral. This gives the coral a "bleached" appearance. Coral can survive in this condition for several weeks but if the warm water persists for longer corals will die. As the oceans continue to warm bleaching is likely to become more frequent and, as the time between bleaching events reduces the likelihood of widespread coral die-off increases. Warm water coral reef bleaching is often observed during surveys.

ii. Acidification: the oceans absorb a significant proportion of the CO_2 emitted by human activity. This causes the ocean to become more acidic. This in turn affects the chemistry of the ocean, particularly the carbonate cycle. As a result, organisms that create calcium carbonate shells or structures (including shellfish and corals) are less able to do so, increasing the likelihood of damage or predation.

iii. Storms: storms are becoming stronger and more frequent. Storms can affect corals in shallow water as wave action breaks corals. This was evident following storm Pabuk, which hit the Terengganu islands in early 2019 causing significant damage to shallow reefs (which was reflected in survey data).

To counter the effects of climate change, there is a need to build the “resilience” of coral reefs so that they are as healthy as possible and thus more likely to withstand or recover from climate-related impacts.

5.3.7 Public Health

The Ministry of Health has implemented a number of programs and activities to monitor certain communicable and environmental diseases that are directly or indirectly related to climate change. To improve population health in an unstable and changing climate, the resilient healthcare system includes a climate-sensitive disease surveillance system as well as capacity building of health personnel to enhance their response and readiness capabilities to the health impacts of climate change.

5.3.7.1 Vector-Borne Diseases

Dengue is one of the mandatory notifiable diseases by medical practitioners in Malaysia under the Prevention and Control of Infectious Diseases Act 1988 (Act 342) and the National Strategy Plan for Dengue Prevention and Control Program (2021-2025). The monitoring of dengue is available through the real time web-based dengue surveillance systems notably the e-Notification, e-Dengue and Dengue Outbreak Management System. There is also a sentinel surveillance of circulating dengue serotype via Dengue Virus Serotype Surveillance Program by National Public Health Laboratory and IMR.

Malaysia has reported zero indigenous cases of human malaria since 2018 and successfully sustained this status for four consecutive years. Therefore, Malaysia has ended the National Strategic Malaria Elimination Plan in 2021. Nevertheless, numerous new strategies have been implemented to prevent malaria re-introduction to the country which include malaria re-introduction risk stratification and risk mapping. An online risk mapping code-named MAGICs.ME is one of the new strategies for malaria prevention, preparedness and response plan.

5.3.7.2 Food and Waterborne Disease

There are five food and waterborne diseases on the list of communicable diseases which are required to be notified under the Prevention and Control of Infectious Diseases Act 1988. These are Cholera, Typhoid/Paratyphoid fevers, Viral hepatitis A, food poisoning and Dysentery.

5.3.7.3 Communicable Disease

Leptospirosis becomes notifiable under the Prevention and Control of Infectious Diseases Act 1988 [Act 342] since 2011. The implementation of control and prevention of leptospirosis include four strategies which are:

i. enhanced surveillance and sharing of information;
ii. coordinated multi-agencies prevention and control activities;
iii. risk reduction; and
iv. research and development.

5.3.7.4 Heat Related Illness

Heat related illnesses are a wide spectrum of disease ranging from heat oedema to heat stroke. Other heat related illnesses include heat exhaustion, heat cramp, heat syncope and heat fatigue. Monitoring of heat related illnesses were developed and carried out since 2016 where hospital-based data such as hospital admissions and mortalities due to heatwave were regularly collected.

5.3.7.5 Non-communicable Respiratory Diseases

Monitoring of diseases related to haze through sentinel clinics were developed since 1998. In 2020, there are a total of 65 sentinel clinics to monitor the trend of upper respiratory tract infections, conjunctivitis and asthma during poor air quality periods. In addition to the monitoring by the sentinel clinics, hospital-based data such as hospital admissions and mortalities of respiratory, cardiovascular, cerebrovascular and other chronic diseases are also collected on a regular basis.

5.3.8 Air Quality Monitoring

The Department of Environment (DOE) under NRES and the Natural Resources and Environment Board (NREB) under the Sarawak Government are the two key agencies responsible to monitor air quality in Malaysia. A total of 65 automatic and 14 manual stations were installed throughout the country in carrying out this task. Monitoring is also further enhanced with one unit of mobile environmental air quality station placed in Peninsular Malaysia, Sabah and Sarawak respectively. In addition, NREB operates five Air Quality Monitoring Stations (AQMS) that are able to detect PM2.5 in Tebedu, Lubok Antu, Lawas, Lundu and Bario with the objective of monitoring the occurrences of haze.

The observed near real-time air quality data such as Air Pollution Index (API) are shared through their websites: http://apims.doe.gov.my/home.html and https://www.nreb.gov.my respectively.

The air quality monitoring components at the 65 DOE's stations are PM10, PM2.5, ground level ozone, carbon monoxide, sulphur dioxide and nitrogen dioxide. The API is calculated based on the concentration of these 6 major components.

CHAPTER 6

6. CAPACITY-BUILDING, EDUCATION, PUBLIC AWARENESS, INFORMATION SHARING AND NETWORKING

6.1 Introduction

Interest and attention on climate change continue to grow within the government, research institutions, private sector, civil society organisations and general public since NC3.

At the policy-making level, the government has enhanced its focus on addressing climate change as illustrated through continuous mainstreaming of mitigation and adaptation elements into the relevant development policies.

Awareness raising and capacity-building efforts among government agencies and key state-owned enterprises in the energy sector saw a significant increase. Workshops and lectures on climate change have become regular feature of these awareness activities to enhance climate change knowledge among their personnel.

The financial and capital sector over the past few years has taken a keen interest on climate change and had carried out a series of awareness programme among its members from regulatory body to private banks and institutional investors.

Civil society organisations with their varied and specific expertise continue to play an active role in increasing the overall awareness and responses of Malaysia in facing the climate change phenomena.

Following the adoption of the Paris Agreement and the spate of climate-related disasters around the world, local media interests were heightened on the importance of international cooperation to address climate change. Media coverage was focused on key global events such as the annual COP and meetings of statutory bodies of the UNFCCC, the IPCC and the United Nations General Assembly's programme on climate change.

6.2 Capacity-building

Relevant government agencies overseeing key emissions sectors have stepped up their respective capacities to meet the periodic reporting requirements of the UNFCCC as well as the dual climate actions in mitigation and adaptation.

6.2.1 Greenhouse Gas Inventory

Malaysia continues to build its institutional capacity in applying the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines in the preparation of its GHG Inventory, enabled by regional and local trainings especially in the energy, IPPU, AFOLU and waste sectors. These efforts were made possible through the UNFCCC's workshops and the annual WGIA, an initiative of Japan via its NIES. In addition, the UNFCCC had provided training for a GHG Inventory review expert.

In the energy sector, TNBR which is the research arm of the country's primary utility company TNB, has conducted training for its personnel to better understand the IPCC methodologies with the aim to develop the CO_2 and non-CO_2 emission factors by flue gas for the electricity sub-sector. The expertise acquired were shared with TNB's power plants personnel across the country. This initiative will also contribute towards enhancing the quality of data collection in the long-run and enable the energy sector GHG Inventory calculation to move to a higher tier.

Another sector where emphasis was made with regards to expertise in applying IPCC methodologies is in the agriculture sector, particularly in the livestock sub-sector. Personnel from the MARDI were trained on the procedures for higher tier estimation of GHG emissions from livestock.

6.2.2 Mitigation

Key agencies implementing mitigation-related efforts are building on their existing training programmes to enhance the capacity of their personnel to ensure the continuity and successful outcomes of those efforts.

6.2.2.1 Energy

In the promotion of renewable energy, the SEDA has continued with its human capital development training programmes in the area of both grid-connected and off-grid photovoltaic system design, installation and maintenance courses. In recent years, TNBR has also followed suit in strengthening the distribution system by rolling out grid-connected photovoltaic design courses covering PV modules, inverter and associated equipment suitable for Malaysia climate conditions.

In addition, SEDA has also extended its grid-connected photovoltaic (GCPV) design course to academia and government agencies to enlarge the pool of expertise in this field. To further enhance the workforce for the renewable energy sector, it has reached out to the low-income group and indigenous communities to participate in GCPV installation courses. SEDA has also engaged the Malaysian Photovoltaic Industry Association in terms of regulatory knowledge, policy direction, technology development and business outlook.

Capacity-building to enhance biogas as another important renewable energy source was also provided by SEDA through training courses in the operation and maintenance of biogas power plant at the operator and supervisory levels.

In support of the NEEAP (2016-2025), courses on energy audits and energy management continue to be conducted by both SEDA and TNBR. In the last four years since NC3, these courses had trained hundreds of energy managers and professionals in measurement and verification from more than a hundred organisations.

Meanwhile, in the construction industry, the CIDB has also continued to produce certified facilitators and assessors through its Malaysian MyCREST programme. This programme helps in the design, construction and operation of energy efficient buildings.

6.2.2.2 Forestry

In implementing the National REDD plus Strategy, capacity and awareness of various stakeholders were enhanced particularly at the sub-national level with technical support from national agency. In addition, Sabah Forestry Department also conducted capacity-building activities to implement its REDD plus strategy.

With rising temperature, changing rainfall patterns and the associated potential for prolonged dry spell, the risk of forest fires incidences is anticipated to increase. Therefore, the forest management protocol has to incorporate forest fire management. The forestry departments have conducted training on fire prevention and control to enhance preparedness for forest fires.

6.2.3 Adaptation

6.2.3.1 Climate Modelling and Vulnerability and Adaptation Assessment

The Southeast Asia Regional Climate Downscaling (SEACLID) and the Coordinated Regional Climate Downscaling Experiment (CORDEX) SEACLID/CORDEX climate modelling initiative presented the research outcomes of its phase one at its final workshop in 2018. Malaysian researchers from universities and research institutes participated in the workshop that enabled them to acquire knowledge on climate projection that would enable them to utilise the projection results for sectoral vulnerability and adaptation assessments.

NAHRIM has carried out several capacity building programmes in regional climate change modelling for Malaysia as well as V&A assessment for the targeted groups of relevant stakeholders.

Between 2018 and 2020, NAHRIM carried out climate modelling for the three regions of the country using the Coupled Model Intercomparison Project Phase 5 dataset by employing dynamical downscaling for 16 realisations under five Global Climate Models and the four Representative Concentration Pathway scenarios of the IPCC Assessment Report 5. It has also completed the sea level rise study for the three regions using statistical downscaling based on 29 Atmosphere-Ocean General Circulation Models (AOGCMs).

In addition, NAHRIM has conducted specific capacity building programmes to strengthen the expertise of officers in assessment of climate vulnerabilities in water resources, sea level rise, sea surface temperature and saltwater intrusion. NAHRIM has produced the Climate Change Adaptation Framework for the water sector which provides strategic planning options to address adverse impacts of climate change and increase sectoral resilience.

NAHRIM has also embarked on V&A training through the development of Malaysia Adaptation Index (MAIN), which summarises the level of vulnerability and readiness of each state in facing the impacts of climate change.

The APEC Climate Centre (APCC) under its Young Scientist Support Program also provided trainings on climate projection downscaling and its applications for V&A assessments.

6.2.3.2 Disaster Risk Reduction

Workshops and training to strengthen linkages between disaster risk reduction and climate change was led by Universiti Kebangsaan Malaysia’s Southeast Asia Disaster Prevention Initiative (SEADPRI-UKM) in collaboration with multiple partners under the aegis of NADMA Malaysia.

With support from the Newton Ungku Omar Fund, SEADPRI-UKM also collaborated with the City Hall of Kuala Lumpur to build the capacity of multi-disciplinary researchers to develop a multi-hazard platform for forecasting climate hazards at the city level. A series of workshops on disaster resilient cities were held to create awareness and enhance understanding among academia, policy-makers, government officers, disaster management personnel and NGOs involved with disaster management on the use of the climate hazards platform for disaster risk reduction.

With funding from International Development Research Centre of Canada (IDRC), SEADPRI-UKM and the State Government of Selangor convened events promoting social entrepreneurship for disaster risk reduction and climate change, to build community resilience. The focus was on strengthening science, technology and innovation that bridges near term climate hazards to long term slow onset and emerging threats at the local level.

6.2.3.3 Agriculture and Food Security

In anticipation of adverse climate impacts on food production, agriculture researchers and officers participated in various training programmes to equip themselves with available tools, skills and knowledge. Researchers were exposed to various climate resilience technologies and practices through capacity-building programmes by international bodies for ASEAN member states.

The Department of Agriculture of Peninsular Malaysia continued its promotion of Good Agriculture Practices (GAP) with a focus on erosion controls for vegetable and fruits farmers. Outreach were made to a few thousand farmers and students through exhibitions, leaflets and symposiums. A demonstration plot on erosion control and field training on soil conservation techniques were among the hands-on initiative carried out.

GAP were also implemented by the oil palm and kenaf plantation industries. The Malaysian Palm Oil Certification Council (MPOCC) provided training on sustainability practices for over 45,000 oil palm smallholders under the national mandatory certification scheme.

MARDI is also spearheading rice genetic research and cooperation with other rice-producing ASEAN members as a climate resilience solution for this staple food.

6.2.3.4 Infrastructure

PETRONAS, the national oil and gas company, has been building internal capacity and raising awareness on climate hazards. This has enabled them to use Geographic Information System (GIS) to compile critical information to assess climate vulnerabilities of its operation and assets to climate change and develop an adaptation plan.

Over the same period TNBR had also been developing the capacity of its staff to carry out V&A assessments of the country's electricity infrastructure including existing coal-fired power plants operated by TNB, with the aim to develop an adaptation guideline to enhance the resilience of these assets.

The Ministry of Health has developed a checklist to assess the vulnerability and resilience of its health facilities across the country.

6.3 Education

Climate change education saw increased interests within the public sector in the past few years. Meanwhile, dissemination of information and knowledge on climate change continues in both formal and informal environmental education through the schools' and higher education institutions' curriculum and extra-curriculum activities.

6.3.1 Formal Environmental Education

The Ministry of Education has incorporated climate change in the geography syllabus of secondary schools as well as in language and science subjects. About 200 teachers from the 13 states and three federal territories were picked to attend the Training of Trainers course. They would in turn replicate the course and pass on the knowledge to 11,775 geography teachers throughout the country's secondary schools.

6.3.2 Informal Environmental Education

The Ministry of Youth and Sports Malaysia has actively engaged youths in impactful programs, aligning with the nation's climate action goals. Initiatives like Rakan Bumi: 3R@Community, Eksplorasi Alam, Rakan Bumi: Plogging@Community, Program Tanam Pokok, Penanaman Bakau and Program Tanam Pokok Sempena LTdL have been conducted which emphasize (i) Empowering youths to champion environmental awareness and eco-friendly practices; (ii) Fostering community cohesion and environmental consciousness among younger generations; (iii) Encouraging eco-conscious habits, fitness activities and conservation initiatives among youth; (iv) Cultivating a deep appreciation for diverse flora and fauna experiences; (v) Instilling a sense of responsibility and environmental stewardship through hands-on activities; (vi) Providing youth-centric fitness programs tailored to different districts; (vii) Elevating youth awareness about the importance of biodiversity and green spaces (viii) Inspiring a profound connection to nature through tree-planting campaigns; (ix) Aligning with climate objectives via initiatives like 'Friend of Earth Program: LTdL Tree Planting

2023; and (x) Involving youths in coastal preservation efforts and promoting sustainable tourism

The Environment Protection Department of Sabah has implemented the *Friends of the Environment* programme among schools in the state since 2003 to inculcate environmental awareness among the schooling population. Activities of the programme is jointly organised with the State Education and Forestry Departments as well as the Sabah Wetlands Conservation Society.

The Climate Change Institute of the National University of Malaysia (Institut Perubahan Iklim, Universiti Kebangsaan Malaysia) organised public lectures to raise awareness among undergraduates, researchers and general public on climate change and its impacts. It also reached out to coastal communities to impart information on sea level rise.

The corporate sector has also stepped up its informal environmental education in tandem with the increase in Corporate Social Responsibilities programmes among the private sector. SWCorp, a waste management corporation has developed training module for the establishment of recycling clubs in both primary and secondary schools. The programme reward participating schools through competitions. The campaign is also extended to the tertiary education institutions.

Sime Darby Plantation, a corporation from the oil palm plantation sector, under its Sime Darby Foundation's Young Sustainability Ambassador programme collaborates with FRIM in inculcating environmental awareness among youth via nature camps. FRIM also provides the corporate sector an avenue to implement greening activities through its tree-planting initiative.

SEDA raised awareness of the sustainable energy agenda of the country through its magazine called 'Sustainable Energy Malaysia' which is distributed to its stakeholders such as ministries, government agencies, embassies, financial institutions and key industry players.

6.3.3 Research Community

To enhance the research capacity and output of academicians, the Academy of Science Malaysia (ASM) held seminars and workshops centred on the IPCC Fifth Assessment Report and played a role in linking local scientists' engagement with the IPCC's process.

In addition, several workshops and dialogues were also convened by ASM to enhance the engagement of local scientists in the IPCC Sixth Assessment cycle of the IPCC. The Academy also held several events to disseminate recent findings of the IPCC to early career researchers and youths.

6.3.4 Public and Corporate Sector

As a key emissions source, the energy sector represented by state-owned enterprises TNB and Petronas are acutely aware that they need to beef up awareness internally and lead by example. Both entities are actively assessing and disclosing their operational impacts in terms of carbon footprints through their annual sustainability reports besides holding regular lectures to sensitise their respective personnel. TNB's initiative is supported by training on carbon footprints assessment provided by its subsidiary, TNBR, across TNB's operating entities.

Special attention was given to growing energy consumption in the information and communications technology (ICT) sector by SEDA. In 2017, SEDA initiated the Data Centre Baseline and the Telecommunication Baseline studies. SEDA also coordinated the Energy Audit Conditional Grant under the 11th Malaysia Plan for commercial buildings to adopt energy management and conservation measures.

In the port and shipping industry, two ports have introduced sustainable practices in their attempts to reduce emissions and green their operations. Kuantan Port, for example, is developing a GHG inventory reporting on its operation and exploring wave energy with Universiti Pertahanan Nasional Malaysia.

The Ministry of Health continues to educate its personnel on climate change and its impacts especially in the area of management of public health during climate-related disasters. It has conducted a workshop among its personnel on the vulnerability and adaptation assessment of climate related health effects. The workshop focused on the linkage between climate and health at specific locations, as well as an assessment of the factors influencing vulnerability. It would serve as the foundation for adaptation plans to reduce vulnerability and improve resilience to climate change.

The Town and Country Planning Department has introduced the concept of Green Neighbourhoods to encourage municipalities and city councils to incorporate mitigation and adaptation elements into their spatial plans.

6.4 Public Awareness

6.4.1. Public Participation

Awareness on climate change among general public is best strengthened by direct participation of the targeted communities.

To enhance the knowledge of the National REDD Plus Strategy, the Sabah Forestry Department conducted a series of workshops to raise awareness of the mechanism and encourage participation of the community in the Lower Kinabatangan River corridor. The workshops involved nearly 200 representatives from the riverine villages. Under its *MySuria* project launched in 2017, SEDA has enabled 332 selected poor households to instal solar rooftop and participate in the Feed-in-Tariff mechanism for a 10-year period. Each family were able to generate an additional RM250 per month by selling electricity to the national grid. In its implementation, SEDA collaborated with regional economic development authorities such as the Northern Corridor Implementing Agency of the Northern Corridor Economic Region. SEDA also implemented two solar PV projects with the state government of Selangor's *Smart Selangor* programme – a GCPV project for a low-cost flat dwelling and an off-grid PV project in an indigenous village.

To increase the visibility of the country's renewable energy adoption efforts, a building-integrated PV (BIPV) was installed above the walkway linking the National Cancer Institute and Hospital Putrajaya which allowed the public to appreciate the effort via a display screen showing the real-time performance of the BIPV system.

To reduce emissions from the waste sector, waste management company SWCorp has rolled out a series of waste minimisation initiatives ranging from recycling bank, upcycling and a "No food wastage during Ramadhan" campaign since 2017.

NAHRIM has continued with its community-based awareness programme on sea level rise through seminars and workshops to equip targeted communities with knowledge and observation skills.

Civil society organisations in Malaysia also played their parts in raising awareness of climate change via their respective programmes. In the past years, World Wide Fund – Malaysia continued with its annual flagship Earth Hour Campaign by collaborating with the city councils of Melaka, Petaling Jaya and Penang. It also expanded its climate agenda via the One Planet City Challenge, a biennial competition that aims to recognise and reward cities for developing low carbon and climate-resilient solutions. The Malaysian Youth Delegation, set up in 2015, continued to lead the climate movement among young Malaysians by offering the opportunity to participate as youth delegates at the annual UNFCCC Conference of Parties. It prepared the participants by exposing them to national and international climate policies through dialogue sessions with respective experts from the government and non-governmental organisations.

Other non-governmental organisations like Sahabat Alam Malaysia (SAM), Malaysian Nature Society (MNS) and Global Environmental Centre (GEC) had maintained a long-standing engagement with local communities and schools through their respective environmental awareness programmes. In the case of MNS and GEC, partnerships were also forged with the private sectors. A key feature of their programmes is tree-planting activity especially in mangrove and peat swamp areas.

In the marine ecosystem, Reef Check Malaysia continues its monitoring of the health of coral reefs at over 200 sites each year with volunteers' help.

The Third World Network (TWN) which tracked the UNFCCC's negotiation process provided its perspectives on the international policy-making space at public forums and the media.

6.4.2 Early Warning System and Disaster Preparedness

As extreme weather events increase over time, development of early warning system and disaster preparedness gained importance to protect lives and properties among vulnerable communities.

The DID provides information on floods, rainfall, river water level and associated flood risks, flood cameras, drought by river flow and drought by dam to the public through a web portal. DID also provides warnings and advice on risk of floods through the national television during the yearly northeast monsoon season.

For communities located close to the frontline of vulnerable infrastructure such as dams, TNBR has embarked on a programme to sensitise local communities including indigenous villagers living close to hydro power stations operated by its parent company TNB. The programme includes evacuation drills involving hundreds of residents and villagers. It has also produced a guidebook on disaster relief management to better coordinate response procedures with non-governmental organisations.

Besides floods, DID also disseminate information on water resources status as early warning on potential drought. The web portal, http://infokemarau.water.gov.my, provides a real time monitoring of drought conditions and a two-month advanced prediction.

Flood warnings efforts of DID is complemented by the Public Works Department's disaster management website that provides latest information on disasters such as floods, landslides, collapsed roads, sunken roads, damaged/collapsed bridges, and others. Apart from disaster information, it also informs public on the status of flood operation rooms.

6.4.3 Green Financing

The financial and capital market sector has embarked on a series of awareness raising campaign to educate bankers, institutional investors and insurers on the importance of adopting sustainability in their operation and greening their investments portfolios. Capital Market Malaysia, Malaysian Association of Asset Managers and Aberdeen Standard Institutional Client and Institutional Investors Council were active in organising seminars and talk to promote sustainability ranging from corporate sustainable reporting to greening capital market products. In its series of Thematic Sustainability Workshop, Bursa Malaysia Berhad (formerly known as the Kuala Lumpur Stock Exchange) has raised awareness on exposure to climate risks, role of the financial sector towards the transition to a low carbon economy.

As the leading authority on sustainable energy, SEDA too played its part in the Malaysian Green Financing Taskforce (MGFT) initiated by the Securities Commission of Malaysia. MGFT's objective is to develop an ecosystem that will support the growth of a viable and sustainable green economy.

SEDA also contributed to the Renewable Energy Value based Intermediation Financing and Investment Impact Assessment Framework (VBIAF) Sectoral Guide Working Group of the Bank Negara (Central Bank) in 2019 which serves as reference or financial institutions intending to incorporate environmental, social and governance (ESG) risks consideration in their own risk management system.

Apart from helping to mainstream the green economy through green product and service expansion, the Malaysian Green Technology and Climate Change Corporation (MGTC) continued its advocacy on energy efficiency, renewable energy, low carbon urban infrastructure and lifestyles in particular on low carbon mobility through programmes such as the International Greentech and Eco Products Exhibition and Conference Malaysia (IGEM).

6.5 Information Sharing and Networking

Collaboration to address the challenges of climate change has continued at the international and regional level. Malaysia's networking in climate actions cover the areas of energy, industrial processes, agriculture, low carbon cities.

At the UNFCCC, UNDP and GCF level, Malaysia's policy-makers were able to build their capacities in key areas of climate actions such as climate finance, adaptation, REDD Plus implementation, development of Nationally Determined Contributions and Enhanced Transparency Framework. The latter two areas are vital aspects towards implementation of the Paris Agreement which gained momentum after it came into force in November, 2016.

Various capacity building efforts in support of the implementation of Paris Agreement were also conducted at the bilateral level between Malaysia and foreign entities such as German Agency for International Cooperation (GIZ), National University of Singapore, National Institute for Environmental Studies of Japan and the European Capacity Building Initiative.

Since 2012, the country's lead agency for sustainable energy, SEDA, has organised the International Sustainable Energy Summit (ISES). The biennial event gathered the international community in the field of sustainable energy to share the latest knowledge and policies and accelerate transformation of the energy sector to achieve the collective climate goals.

In 2018, SEDA represents Malaysia in the International Energy Agency Photovoltaic Power System Programme Executive Committee. The representation enabled Malaysia to further develop its solar PV industry and scale-up adoption of the technology. Besides IEA, SEDA also represents Malaysia at the International Renewable Energy Agency.

At the ASEAN level, the country has been in active collaboration with the ASEAN Centre for Energy in the area of energy management. Malaysia is an active participant of the ASEAN Minister of Energy Meeting and the Senior Officials Meeting on Energy which are key political platform for regional cooperation on energy. Malaysia held the chair of the Renewable Energy Sub-sector Network (RE-SSN) since 2009 and the chairmanship was helmed by SEDA between 2012 and 2019. Malaysian companies were keen supporters of the ASEAN Energy Awards (AEA) initiative that was launched in 2000 to promote awareness on best practices in energy efficiency and conservation in buildings, industries and energy management, renewable energy, and clean coal technology.

The iron and steel industry of Malaysia has strong engagement at the regional level by participating in forums and conferences promoting and exchanging solutions to green the industry. As a member of the South East Asia Iron and Steel Institute, the Malaysian Iron and Steel Industry Federation (MISIF) participate in the annual ASEAN-Japan Steel Initiative which seek to enhance cooperation on energy saving and environmental protection for a sustainable steel industry.

In the field of agriculture, Malaysia has participated in the Climate Smart Agriculture course with a focus on rice cultivation organised by the ASEAN Secretariat and Ministry of Agriculture, Forestry and Fisheries of Japan.

Another collaboration related to energy efficiency is in the field of the production of highly-efficient LED through the Gallium nitrate-on-Gallium nitrate (GOG) between researchers from two public and one private university in Malaysia and researchers from the University California of Santa Barbara.

As Malaysia experience rapid urbanisation, it is keen to adopt low carbon city strategies. Since 2017, 19 municipality and city councils have participated in the Global Covenant of Mayors for Climate and Energy initiative.

Under the FAO's Gulf of Thailand (GoT) Large Marine Ecosystem initiative, the Department of Fisheries is participating in the activity of building the resilience of the marine ecosystem in the east coast of Peninsular Malaysia.

The Asian Network on Climate Science and Technology (ANCST) coordinated by SEADPRI-UKM continued to facilitate collaboration and exchange of information between researchers engaged in scientific and technological aspects of climate change and climate-driven disasters specific to Asian conditions and phenomena. With seed-funding from the Cambridge Malaysian Education and Development Trust and Malaysian Commonwealth Studies Centre (CMEDT/MCSC), ANCST has convened about five events annually with multiple institutions involving researchers, policymakers, private sector practitioners and early career researchers. The reach of ANCST includes providing inputs relevant to the tropics to global institutions such as the IPCC, United Nations Office for Disaster Risk Reduction (UNDRR) and the International Science Council (ISC).

The Sabah's Ministry of Tourism, Culture and Environment collaborated with the Conference of Earth Environment from Akita (CEEA), Japan in a multi-year public awareness raising programme on climate change. Two workshops were organised under phase One of the collaboration from 2016 to 2019 involving students, teachers, parents and local community members.

6.6 Gender Participation

In line with the Enhanced Lima Work Programme on Gender (LPWG) and its gender action plan[4] which calls for women's full, equal and meaningful participation in the international climate process, the Committee conducted 97 engagements as part of the NC4 process in the form of meetings, workshops, trainings and consultations involving a total of 1,699 people (959 women; 750 men). Moreover, approximately 42% of women held technical positions (Table 6.1) in the national climate change technical committees and working groups, namely the Technical Committee on Climate Change, Technical Working Group on GHG Inventory, Technical Working

[4] UNFCCC. The Gender Action Plan. Available at https://unfccc.int/topics/gender/workstreams/the-gender-action-plan

Group on Mitigation, Technical Working Group on Vulnerability and Adaptation, Technical Working Group on Research and Systematic Observation, Technical Working Group on Finance, Technology and Needs and Technical Working Group on Transparency Related Activities as well as their Sub-Working Groups as shown in Figure 1.10 in Chapter 1 on National Circumstances.

Table 6.1: Women's Engagement and Participation in the NC4 Process, 2022-2023

Indicator		Number, Percentage
1.	Women and men participating in consultations and engagement workshops by KASA	Female: 959 (56.4%) Male: 740 (43.55%)
2.	Number of women in technical positions in National Climate Change Committees	Female: 68 (41.7%) Male: 95 (58.2%)

Source: Ministry of Natural Resources, Environment and Climate Change (2022-2023)

Malaysia continues to build awareness on climate change issues, and in doing so tries to actively engage women in these initiatives. Between 2017 and 2019, ministries, government agencies, public institutions and corporations conducted a variety of Capacity Building, Education, Public Awareness, Information Sharing, and Networking (CEPAIN) initiatives on climate change awareness (see Table 6.2).

Table 6.2: Women's Engagement and Participation in Climate Change Initiatives, 2017-2019

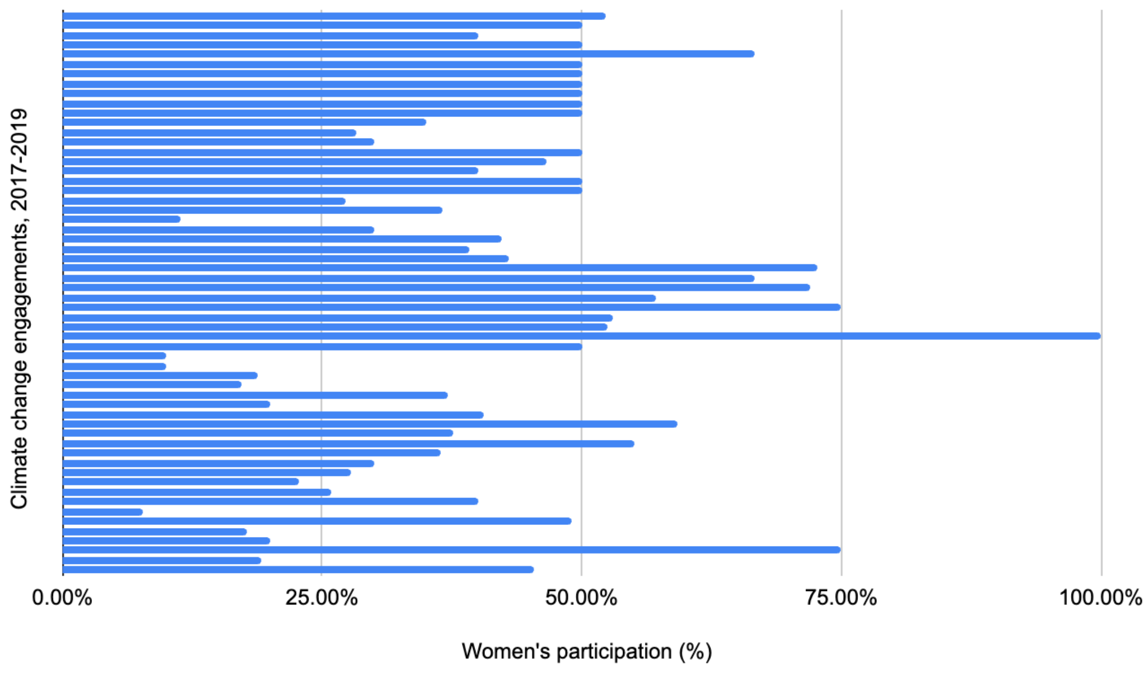
Indicator	Number/ Percentage
Women and men participating in consultation and engagement workshops on climate change (CEPAIN, 2017-2019)	Female: 15,912 (31.3%) Male: 34,922 (68.6%)

Source: Ministry of Natural Resources, Environment and Climate Change (2022)

Slightly more than half (53%) of the initiatives organised for the public sector saw female participation rates of 50% and higher. Events with lower numbers of female participation were reflective of industries with traditionally low numbers of women, such as technical fields within forestry such as carbon stocks, climate financing, GIS mapping; agricultural management; and clean energy adaptation. Similarly, none of the initiatives organised for actors within the private sector (n=14) exceeded 50%

participation of women in industries such as agriculture, transportation management, and construction, nor did trainings that involved communities.

Figure 6.1: Percentage Women's Engagement and Participation in Climate Change Activities, 2017-2019



Source: Ministry of Natural Resources, Environment and Climate Change (2022)

6.6.1 Gaps and Opportunities

The gender profile of Malaysia as well as the main climate change trends, policies and programmes in Malaysia provides a data set for each sector, but little to no nexus is made by either of the sectors. Information that is available through sporadic and ad hoc studies point towards the negative impacts of climate change on the basis of gender[5,6,7] but also indicate a low understanding of the link between environmental sustainability and gender equality, to cultural and social norms. The sectors working

[5] UNICEF, Universiti Kebangsaan Malaysia, Universiti Malaysia Sabah (2021). The impact of climate change on children: A Malaysian perspective. Available at https://www.unicef.org/malaysia/reports/impact-climate-change-children

[6] UKM (2015). Women Bore The Brunt Of Flood Disasters. Available athttps://www.ukm.my/pkwtfh/news/women-bore-the-brunt-of-flood-disasters/

[7] ARROW and the Penita Initiative (2016). A Scoping Study: A Focus on Indigenous Communities in Malaysia. Available at https://arrow.org.my/wp-content/uploads/2016/05/Climate-Change-and-SRHR-Scoping-Study_Malaysia.pdf.

on climate change have not yet taken the specific needs, experiences and knowledge of women and men into account to inform a gender-responsive approach to climate change.

This is the first time that Malaysia has tried to address and incorporate gender issues into the national communication process guided by the UNDP Toolkit on Gender Responsive National Communications and other relevant UN tools and methodologies. In line with the LPWG, Malaysia has identified several indicators under each of the Priority Areas that will guide its focus in developing a holistic gender-responsive approach moving forward, namely:

Priority area A: Capacity building, knowledge management and communication

- **A.1** Strengthen capacity building efforts for government agencies and other stakeholders in mainstreaming gender in formulating, monitoring, implementing and reviewing, as appropriate, national climate change policies, plans, strategies and action, including nationally determined contributions, national adaptation plans and national communications.
- **A.2** Appoint a national gender focal point for UNFCCC
- **A.3** Enhance capacity building for government agencies and other stakeholders to collect, analyse and apply sex-disaggregated data and gender analysis in the context of climate change, where applicable.
- **A.4** Strengthen the evidence base and understanding of the differentiated impacts of climate change on men and women, and the role of women as agents of change and on opportunities for women.

Priority area B: Gender balance, participation and women's leadership

- **B.1** Promote initiatives for capacity building in leadership, negotiation and facilitation of negotiation for women delegates, including through webinars and in-session training to enhance women's participation in the UNFCCC process.
- **B.2** Promote travel funds as a means of supporting the equal participation of women in all national delegations at the UNFCCC sessions, as well as funds to support the participation of grass roots local and indigenous peoples' communities, and share information on travel funding with the UNFCCC secretariat.

Priority area C: Gender-responsive implementation and means of implementation

- **C.1** Support capacity building on gender budgeting, including on the integration of gender-responsive budgeting into national budgets to advance gender-responsive climate policies, plans, strategies and action, as appropriate.
- **C.2** Using the financial and technical support made available by various climate funds, promote the strengthening of gender integration into climate policies, plans, strategies and action, as appropriate, including good practices to facilitate access to climate finance for grass-roots women's organisations and indigenous peoples and local communities.
- **C.3** Promote the deployment of gender-responsive technological solutions to address climate change, including strengthening, protecting and preserving local, indigenous and traditional knowledge and practices in different sectors

and for improving climate resilience, and by fostering women's and girls' full participation and leadership in science, technology, research and development.

- **C.4** Support the collection and consolidation of information and expertise on gender and climate change in sectors and thematic areas as well as identifying experts on gender and climate change, as needed, and enhance knowledge platforms on gender and climate change.
- **C.5** Engage women's groups and national women and gender institutions in the process of developing, implementing, and updating climate policies, plans, strategies and action, as appropriate, at all levels.
- **C.6** Exchange information on lessons learned among neighbouring countries in the region that have integrated gender into national climate policies, plans, strategies and actions, as appropriate and on the actions, countries are taking to mainstream gender in any updates thereto, as appropriate.
- **C.7** Enhance the availability of sex-disaggregated data for gender analysis, taking into consideration multidimensional factors, to better inform gender-responsive climate policies, plans, strategies and action, as appropriate.

Priority area D: Monitoring and reporting

- **D.1** Strengthen the monitoring and reporting on women in leadership positions within the UNFCCC process in the context of the gender composition report submitted by the secretariat.
- **D.2** Monitor and report on the implementation of gender-responsive climate policies, plans, strategies and action, as appropriate, reported by Parties in regular reports and communications under the UNFCCC process.

CHAPTER 7

7. CONSTRAINTS, GAPS, LEVEL OF SUPPORT RECEIVED AND NEEDS

7.1 Introduction

This chapter is an updated summary of the Constraints, Gaps, the Level of Support Received and Needs as reported in Chapter 4 of the Fourth Biennial Update Report whereby the details can be found in the chapter titled Level of Support Received, Constraints, Gaps and Needs.

Financial, technical and capacity building support from international sources were received by federal and state agencies from multilateral and bilateral sources to implement climate change actions.

7.2 Constraints and Gaps

Challenges remain in implementing Malaysia's commitment to address climate change and its impacts. Some of the challenges were identified by the Team of Technical Experts (TTE) during the International Consultation and Analysis of Malaysia's Third BUR.

7.2.1 GHG Inventory and GHG Emission Projection

For GHG inventory and emission projection, the challenges include the development of country-specific emission factors, improvement of activity data collection, and long-term modelling tools for projections. Estimating GHG emissions and removals from some categories are constrained by incomplete or lack of activity data and most categories lack country specific emission factors.

For BUR3, the TTE in consultation with Malaysia identified a need for capacity-building that could facilitate the Party's transition to the enhanced transparency framework under the Paris Agreement, namely enhancing the national capacity for future scenario analysis, including factor analysis and decomposition analysis at the sectoral level.

As stated in BUR4, Malaysia is continuing to improve its institutional arrangement, activity data collection, analysis and archiving for its GHG inventory. Efforts are being concentrated on improving the disaggregation and completeness of the activity data according to the 2006 IPCC Guidelines and developing country specific emission factors for the key categories. A National GHG Inventory Improvement Plan for emission factors is being implemented under the 12th Malaysia Plan (2021-2025), however capacity building is still needed for realising these plans.

7.2.2 Mitigation

Quantification of mitigation outcomes continues to be a challenge especially when policy measures do not address GHG emissions reduction. Improvement in the accounting methodologies for all the sectors (energy, IPPU, waste, agriculture and LULUCF sectors) could be further enhanced.

Implementation of mitigation actions requires access to suitable cost-effective technologies. At the current moment, access to cleaner technology remains a constraint, hence mitigation opportunities are limited especially for the IPPU sector. For the agriculture sector, mitigation opportunities are restrained by the need to prioritise food security and livelihood of farmers. Despite these challenges, policy measures are being developed especially for the energy and IPPU sectors in order to guide Malaysia's NDC implementation and pathway towards net-zero emissions as early as 2050. The Securities Commission, Central Bank and Bursa Malaysia require companies and financial institutions to incorporate ESG into their reporting of sustainability. These actions include the role of carbon markets, the adoption of new technologies such as carbon capture, utilisation and storage and the enhanced usage of nature-based solutions to reduce emissions. The waste sector has already set ambitious targets for recycling.

7.2.3 Adaptation

The constraints and gaps for vulnerability assessment and adaptation measures had been presented in detail for each of the sectors in Chapter 4. While vulnerability assessment has become a periodic routine, capacity buildings to increase the expertise of the personnel involved in the climate projection, vulnerability assessment and adaptation needs identification and implementation is required. To this end, Malaysia is in the process of getting approval for financial support from GCF to develop a comprehensive National Adaptation Plan.

7.3 Level of Support Received

The main source of international financial support is through the Global Environmental Facility (GEF), one of the two operating entities of the UNFCCC's financial mechanism from cycle 1 to 7 (June 1994 to June 2022). The funding provided by GEF, other multilateral agencies and bilateral sources were channeled through specific projects.

Under GEF cycle 4 to 7 (June 2006 – June 2022), Malaysia was allocated an indicative sum of USD43.7 million and utilized USD38 million which was used to develop the country's institutional and technical capacity on the reporting obligations to the UNFCCC as well as the implementation of mitigation actions. These actions were facilitated by the United Nations Development Programme (UNDP), the United Nations Industrial Development Organisation (UNIDO) and the International Fund for Agricultural Development (IFAD).

Financial support through GEF-6 and GEF-7 cycles were primarily used to build up technical and technological capacities in transport, energy, forestry (including peatland), low carbon cities and community empowerment projects.

The amount of funding provided by GEF for NC4 was USD500,000. It should be noted that in the preparation of BUR4 which was submitted to the UNFCCC on 31st December 2022, the allocation of USD352,000 from GEF for BUR3 was used. This was made possible as the balance from BUR2's allocation was used to prepare BUR3 which was submitted on 31 December 2020.

The other UNFCCC's financial mechanism operating entities, the Green Climate Fund (GCF) has provided readiness support for Malaysia to identify energy sector prioritisation project, potential direct access entity and enhance its implementation framework to access results-based payment for the forestry sector.

Other significant financial assistance is in the area of adaptation from the United Kingdom with the allocation of £875,000 to develop capacity in forecasting local level climate extremes and physical hazards as well as community level outreach for the city of Kuala Lumpur.

In the area of capacity-building, Malaysia received a fairly wide range of trainings between 2017 and 2019. Trainings in the areas of GHG inventory, mitigation (measurement, reporting and verifying emissions data), adaptation planning, implementing and enhancing Nationally Determined Contributions (NDCs), climate negotiations, climate finance and Article 6 and 13 of the Paris Agreement were provided by the UNFCCC's Consultative Group of Experts, the Intergovernmental Panel on Climate Change, GCF, various multilateral organisations as well as from Annex I and non-Annex I Parties such as the European Capacity Building Initiative, Japan International Cooperation Agency, the German Agency for International Cooperation (GIZ) and the China-ASEAN workshop organized by China.

At the sub-national level, the states of Johor and Melaka have received capacity-building from the United Kingdom Prosperity Fund's Future Cities Programme and the Japanese Joint Crediting Mechanism's City to City Collaboration for Building Energy Monitoring and Reporting System.

7.4 Needs

Malaysia is only beginning to report on its progress on NDC implementation and additional technical capacity-building and financial assistance would be needed to develop systems to track its NDC implementation and cooperative approaches (Article 6 of the Paris Agreement).

Needs for external financial, technical/technology and capacity-building support in the thematic areas of GHG inventories, mitigation and adaptation had been identified by the proponent agencies and nationally agreed upon through workshop consultations and reviewed by the Technical Working Group on Finance and Needs as well as endorsed by the National Steering Committee on Climate Change. These has been detailed in the BUR4 report.

An estimated amount of USD2.25 million in international funding is required for GHG inventory improvement. To implement the identified mitigation actions, major financial support is required by the iron and steel industry to the tune of over USD46 million. For adaptation, a preliminary estimate of USD63.6 million is required for various initiatives to enhance resilience measures throughout the country.

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Ministry of Economy (Energy Division, Macroeconomics Division, and Environmental and Natural Resources Division)

Ministry of Local Government Development
Ministry of Investment, Trade and Industry
Ministry of Plantation and Commodities
Ministry of Transport
National Solid Waste Management Department
Sabah State Economic Planning Unit
Sarawak Economic Planning Unit
SIRIM Berhad
Sustainable Energy Development Authority Malaysia

Contributors
Civil Aviation Authority of Malaysia
Department of Agriculture Peninsular Malaysia
Department of Agriculture Sabah
Department of Agriculture Sarawak
Department of Environment
Department of Survey and Mapping Malaysia
Department of Town and Country Planning
Department of Veterinary Services
Department of Wildlife and National Parks
Energy Commission
Environment Protection Department Sabah
Forest Department Peninsular Malaysia
Green Building Index Sdn Bhd
Indah Water Konsortium Sdn Bhd
Land Public Transport Commission
Malaysia Automotive Institute
Malaysia Investment Development Authority
Malaysian Cocoa Board
Malaysian Institute of Road Safety Research
Malaysian Palm Oil Board
Malaysian Timber Industry Board
Marine Department Malaysia
Melaka Green Technology Corporation
Ministry of Domestic Trade and Costs of Living
Ministry of Economy
Ministry of Energy and Environmental Sustainability Sarawak
Ministry of Finance
Ministry of Local Government and Housing Sabah
Ministry of Public Health, Housing and Local Government Sarawak
Ministry of Utilities Sarawak
National Landscape Department
National Solid Waste Management Department
Natural Resources and Environmental Board Sarawak
PETRONAS

Sabah Electricity Sdn. Bhd.
Sabah Forest Department
Sabah Parks
Sabah Wildlife Department
Sarawak Energy Berhad
Sarawak Forest Department
Sarawak Forestry Corporation
Sewerage Service Department
Single Buyer
SME Corporation Malaysia
Solid Waste and Public Cleansing Management Corporation
State Governments
TNB Research Sdn. Bhd.
Universiti Kebangsaan Malaysia

TRANSPARENCY RELATED ACTIVITIES
Lead Ministry and Lead Agency
Ministry of Natural Resources and Environmental Sustainability
Forest Research Institute Malaysia

Members (Energy)
Energy Commission
Ministry of Economy
Ministry of Plantation and Commodities
Ministry of Transport
Ministry of Energy and Environmental Sustainability Sarawak
Sabah Electricity Sdn Bhd
Sabah State Economic Planning Unit
Sarawak Energy Berhad
Single Buyer Department

Members (IPPU)
Department of Environment
Department of Mineral and Geoscience Malaysia
Malaysia Investment Development Authority
Ministry of Investment, Trade and Industry
Sabah Electricity Sdn. Bhd.
Sarawak Energy Berhad
SIRIM Berhad
TNB Research
UNITEN R&D Sdn Bhd.

Members (Waste)
Department of Environment
Indah Water Konsortium Sdn. Bhd.
Malaysian Palm Oil Board
Malaysian Rubber Board
Ministry of Investment, Trade and Industry
National Solid Waste Management Department
PETRONAS

Solid Waste Management and Public Cleansing Corporation

Members (Agriculture and LULUCF)

Biodiversity and Forestry Management Division, Ministry of Natural Resources and Environmental Sustainability
Department of Agriculture Peninsular Malaysia
Department of Agriculture Sabah
Department of Agriculture Sarawak
Department of Lands and Surveys, Sabah
Department of Statistics Malaysia
Department of Survey and Mapping Malaysia
Department of Town and Country Planning
Department of Wildlife and National Parks Peninsular Malaysia
Economic Planning Unit Sarawak
Economic Planning Unit Sabah
Environment and Climate Change
Forest Department Sarawak
Forestry Department Peninsular Malaysia
Land and Survey Department Sarawak
Ministry of Agriculture, Fisheries and Food Industry Sabah
Ministry of Agriculture and Food Security
Ministry of Food Industry, Commodity and Regional Development Sarawak
Ministry of Natural Resources and Urban Development Sarawak
Ministry of Plantation and Commodities
Ministry of Local Government Development
Malaysian Agriculture Research and Development Institute
Malaysian Cocoa Board
Malaysian Timber Industry Board
Malaysian Palm Oil Board
Malaysian Rubber Board
Malaysian Space Agency
National Landscape Department
Natural Resource Office, Sabah
Sabah Forestry Department

VULNERABILITY AND ADAPTATION

Lead Agency

National Water Research Institute of Malaysia (NAHRIM)

Sector Lead Agencies and Members

Department of Irrigation and Drainage Malaysia - Water and Coastal Resources
Malaysian Agriculture Research and Development Institute - Agriculture and Food Security
Forestry Department Peninsular Malaysia - Forest and Biodiversity
Department of Town and Country Planning - Cities, Built Environment and Infrastructure
Energy Division, Ministry of Economy - Energy
Institute of Medical Research - Public Health

Contributors
Department of Agriculture Malaysia
Department of Agriculture Sabah
Department of Agriculture Sarawak
Department of Environment
Department of Fisheries Malaysia
Department of Irrigation and Drainage Sarawak
Department of Mineral and Geoscience Malaysia
Department of Social Welfare Malaysia
Department of Statistics Malaysia
Department of Veterinary Services Malaysia
Department of Water Supply, Federal Territory of Labuan
Department of Wildlife and National Parks Peninsular Malaysia
Energy Commission
Fisheries Research Institute
Forest Department Sarawak
Forest Research Institute Malaysia
Hibiscus Petroleum Berhad
Indah Water Consortium
Integrated Agriculture Development Area Barat Laut Selangor
Kelantan State Water Resources Department
Kemubu Agricultural Development Authority
Kuching Water Board
Land Public Transport Agency
Malayan Railway Limited
Malaysia Airports Holdings Berhad
Malaysian Cocoa Board
Malaysian Highway Authority
Malaysian Meteorological Department
Malaysian Palm Oil Board
Malaysian Rubber Board
Maritime Institute of Malaysia
Melaka Water Regulatory Body
Ministry of Agriculture and Food Security
Ministry of Health
Ministry Of Local Government Development
Ministry of Natural Resources and Environmental Sustainability
Ministry of Transport Malaysia
Ministry of Works Malaysia
Muda Agricultural Development Authority
National Disaster Management Agency
National Petroleum Limited
National Solid Waste Management Department
National Water Service Commissions
Pahang Water Regulatory Body
Perak Water Board
Public Works Department Malaysia
Reef Check Malaysia
Road Transport Department
Sabah Electricity Sdn. Bhd.

Sabah Forestry Department
Sabah Parks
Sabah Rubber Industry Board
Sabah State Water Department
Sabah Wildlife Department
Sarawak Energy Berhad
Sarawak Forestry Cooperation
Sarawak Rural Water Supply Department
Selangor Water Management Authority
Solid Waste Management and Public Cleansing Corporation
State Health Departments
Sustainable Energy Development Authority
Tenaga Nasional Berhad
Terengganu Water Resources Board
The Johor Water Regulatory Body
TNB Research
Universiti Tenaga Nasional - Institute Energy Policy and Research
Water Asset Management Berhad
Water Regulatory Division, Penang State Government
Water Supply Division, NRES

RESEARCH AND SYSTEMATIC OBSERVATION

Lead Agency
Malaysia Meteorological Department

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Advanced Lightning, Energy & Power Research, Universiti Putra Malaysia (UPM)
Department of Biological Science, Sunway University
Department of Earth Sciences and Environment, Universiti Kebangsaan Malaysia
Department of Environment
Department of Irrigation and Drainage
Department of Survey and Mapping Malaysia
Forest Research Institute Malaysia
Forestry Department Peninsular Malaysia
Institute of Climate Change, University Kebangsaan Malaysia
Institute of Ocean and Earth Sciences, Universiti Malaya
Institute for Medical Research
Malaysian Agriculture Research and Development Institute
Malaysian Cocoa Board
Malaysian Green Technology and Climate Change Corporation
Malaysian Palm Oil Board
Malaysian Rubber Board
Ministry of Local Government Development
National Water Research Institute of Malaysia
Natural Resources and Environment Board Sarawak
Reef Check Malaysia
Sarawak Biodiversity Centre
Sarawak Tropical Peat Research Institute
SIRIM Bhd.

Solar Energy Research Institute, Universiti Kebangsaan Malaysia
TNB Research
WWF-Malaysia

CAPACITY-BUILDING, EDUCATION, PUBLIC AWARENESS, INFORMATION SHARING AND NETWORKING

Lead Ministry
Ministry of Natural Resources and Environmental Sustainability

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Academy of Sciences Malaysia
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Climate Change Institute of the National University of Malaysia
Construction Industry Development Board
Department of Agriculture of Peninsular Malaysia
Department of Fisheries of Peninsular Malaysia
Department of Irrigation and Drainage
Environment Protection Department of Sabah
Forest Research Institute Malaysia
Forestry Department Peninsular Malaysia
Institute of Medical Research
Iskandar Regional Development Authority
Kuantan Port Authority
Malaysia Agriculture Research and Development Institute
Malaysian Cocoa Board
Malaysian Iron and Steel Industry Federation
Malaysian Palm Oil Certification Council
Malaysian Palm Oil Council
Ministry of Education
Ministry of Health
Ministry of Local Government Development
Ministry of Plantation and Commodities
MRT Corp
National Water Research Institute of Malaysia
National Landscape Department
Northern Corridor Implementation Authority
PETRONAS
Public Works Department
Sabah Forestry Department
SME Corp
Southeast Asia Disaster Prevention Initiative - National University Malaysia
Sustainable Energy Development Authority
SW Corp
TNB Research
Town and Country Planning Department

FINANCE, TECHNOLOGY AND NEEDS

Lead Ministries
Ministry of Finance
Ministry of Science, Technology and Innovation (MOSTI)

Members
Bank Negara Malaysia
Department of Environment
Forest Department Sarawak
Forestry Department of Peninsular Malaysia
Ministry of Agriculture and Food Security
Ministry of Economy
Ministry of Health
Ministry of Investment, Trade and Industry
Ministry of Local Government Development
Ministry of Natural Resources and Environmental Sustainability
Ministry of Plantation and Commodities
Ministry of Transport
Sabah Forestry Department
Securities Commission Malaysia

TECHNICAL COMMITTEE ON CLIMATE CHANGE (TCCC)

Deputy Secretary-General, Ministry of Natural Resources and Environmental Sustainability (Chair)
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Forest Research Institute Malaysia
Ministry of Economy
Ministry of Finance
Malaysia Meteorological Department
National Water Research Institute of Malaysia

NATIONAL STEERING COMMITTEE ON CLIMATE CHANGE (NSCCC)

Secretary General Ministry of Natural Resources and Environmental Sustainability (Chair)
Climate Change Division, Ministry of Natural Resources and Environmental Sustainability (Secretariat)
Ministry of Economy
Ministry of Finance
Ministry of Foreign Affairs
Ministry of Transport
Ministry of Local Government Development
Ministry of Investment, Trade and Industry
Ministry of Agriculture and Food Security
Ministry of Science, Technology and Innovation
Ministry of Plantation and Commodities
Ministry of Women, Family and Community Development
Ministry of Works
Attorney General Chambers

Department of Environment
National Water Research Institute of Malaysia
Malaysian Meteorological Department
Forest Research Institute Malaysia
National Disaster Management Agency
Department of Town and Country Planning
Malaysian Green Technology and Climate Change Corporation
Southeast Asia Disaster Prevention Research Institute
Centre for Environment, Technology and Development, Malaysia
Malaysia Nature Society
Environmental Protection Society Malaysia
WWF Malaysia

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