PAGTANAW 2050

THE PHILIPPINE FORESIGHT

Science • Technology • Innovation

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FOREWORD

The Department of Science and Technology (DOST) has always stood at the forefront of the country's scientific and technological advancement, with the National Academy of Science and Technology, Philippines (NAST PHL) serving to honor and promote the nation's science capital towards developing a truly Filipino productive science culture.

This complement came to my mind when, in 2018, I was invited by the Akademi Sains Malaysia (ASM) on the occasion of the Akademi's presentation of its "Malaysia's Outlook 2050" to their Prime Minister. Inspired by the ASM's notable output, I challenged the NAST PHL to undertake a similar Foresight study for Science, Technology, and Innovation (STI) in our own country. The NAST PHL proposal to develop a 30-year STI Foresight, including strategic plans, was quickly approved for funding by the DOST Executive Committee the following year. The NAST PHL was able to complete the first and second versions of the country's STI Foresight document, aptly entitled PAGTANAW—or "looking ahead"—2050, even despite the technical and other unprecedented difficulties brought about by the COVID-19 pandemic.

PAGTANAW 2050 includes a compendium of STI megatrends; global and national societal goals; transdisciplinary and interdisciplinary operational areas; and current and emerging technologies relevant to the nation's development. A backcast from our shared vision of a desired future three decades hence to the pre- and peri-pandemic situation of today revealed valuable insights that suggest significant drivers of change and plausible STI development paths, moving forward. These pathways are laid out in PAGTANAW 2050's STI Roadmap, a guide to national development that traces the trajectories of the enablers, drivers, and opportunities that are seen to shape Philippine STI for the next three decades.

This Foresight document is firmly grounded on the Filipino people's aspirations within the context of our natural and physical endowments—an archipelago with abundant marine resources—as well as our shared Filipino values and skills, and other potentials as contained in our Constitution and other national institutions. By harnessing these strengths and potentials, we look forward to growing into an economically vibrant and outward-oriented "Prosperous Maritime Archipelago".

My thanks goes out to NAST PHL President Academician Rhodora Azanza, the Foresight Project Leader; Academician William Padolina, chair of the Foresight Steering Committee; the members of the Steering Committee itself, comprised of National Scientists and past secretaries of the DOST; and so many others in the science community, stakeholders who contributed to the making of this NAST PHL STI Foresight document. It is indeed an undertaking of immense responsibility, a decisive furthering of the aspirations of the DOST and the NAST PHL for a progressive Philippines anchored on science in service of the people.

This NAST PHL initiative is a big step towards designing and implementing integrated yet time-specific strategies for a prosperous, inclusive, and agile Philippine future.

Honorable Fortunato T. de la Peña
Secretary
Department of Science and Technology

PREFACE

Despite a brief period of fast-paced economic growth in the first decades of the 21st century, the Philippines still lags behind its neighbors in Southeast Asia and is leagues behind the most competitive and best governed societies in the region and the rest of the world. The country also has yet to achieve most of the United Nations Sustainable Development Goals, which are part of a global call to action to end poverty, protect the planet, and ensure that all people experience peace and prosperity.

The Philippines faces two major challenges in relation to inclusive growth and competitiveness, and to being mainstreamed into the global economy: first, the internal need to address the science, technology, and innovation (STI) support required by the country's burgeoning population; and secondly, the need to address the continuing gaps in the level of science and technology (S&T) between the Philippines and other advanced countries.

Both these hurdles are key areas of concern for the National Academy of Science and Technology, Philippines (NAST PHL), which is mandated to advise the President and his Cabinet on S&T matters. We firmly recognize that decisions about the Filipino people and Philippine society should be based on evidence and logical analysis, hence the urgency of crafting this Foresight in order to forward our vision of a progressive Philippines anchored in science. We embarked on the development of a Philippine foresight and strategic plan for the next three decades (2019–2050) in order to address the country's future needs and demand for scientific and technological interventions. This document is the first solid step in this journey of progress. We are proud and honored to have been able to rally this collective effort from various stakeholders, public and private, from all across the country.

The main goal of this Foresight document, entitled PAGTANAW 2050 ("looking ahead"), is to chart a strategic path by anticipating the factors that will influence the development of the Philippines' scientific capital in the years leading up to 2050. It is based on a rigorous evaluation of key trends in science, technology, and innovation (STI) in the Philippine setting. It is meant to serve as a planning device towards achieving concrete goals and designing strategic plans that shall transcend political periods whilst aiming for inclusive growth, sustainability, and competitiveness in STI.

Herein is a compendium of megatrends; global and national societal goals; and transdisciplinary/interdisciplinary operational areas, including current and emerging technologies with consideration of the pre-, peri-, and post-pandemic period. We delve into probable and significant drivers of change, and provide insights and reflections on the plausible development paths to the achievement of Filipino aspirations as expressed in the 1987 Philippine Constitution; the various Philippine Development Plans; the United Nations Sustainable Development Goals (SDGs); the Department of Science and Technology Harmonized National Research and Development Agenda; and AmBisyon Natin 2040, which was conducted in 2016, just four years before the pandemic.

It is the conclusion of the NAST PHL and the recommendation of this Foresight that the above aspirations can be achieved by acknowledging and enhancing our existence as a Prosperous Archipelagic, Maritime Nation, diplomatically asserting our rights over the resources in our marine environment.

To that end, we have identified 12 key operational areas, namely: Blue Economy; Governance; Business and Trade; Digital Transformation and Information and Communications Technology; Science Education and Talent Retention; Food Security and Nutrition; Health Systems; Energy; Water; Environment and Climate Change; Shelter, Transportation, and Other Infrastructure; and Space Exploration. It is our hope that with this Foresight, we can achieve the S&T aspirations of the Filipino people by 2050.

PAGTANAW 2050 would not have been possible without the assistance and guidance of the Department of Science and Technology and its various attached agencies, particularly the project monitoring agency, the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development. We are continually indebted to the Hon. Fortunato T. De La Peña, Usec. Rowena Cristina L. Guevara, Usec. Renato U. Solidum Jr., and Usec. Sancho A. Mabborang for their trust and support of this Foresight.

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LIST OF ACRONYMS

Acronym	Meaning
1IR	First Industrial Revolution
2IR	Second Industrial Revolution
3IR	Third Industrial Revolution
AANR	Agriculture, Aquatic and Natural Resources
ABNJ	Areas Beyond National Jurisdiction
ADB	Asian Development Bank
ADMU	Ateneo De Manila University
AFP	Armed Forces of the Philippines
AI	Artificial Intelligence
AQMF	Air Quality Management Fund
AR	Augmented Reality
ARISE	Access to Resources and Innovations in Science Education
ARMM	Autonomous Region of Muslim Mindanao *(see BARMM)*
ARPANET	Advanced Research Projects Agency Network
ARWU	Academic Ranking of World Universities
ASEAN	Association of Southeast Asian Nations
ASEAN	Association of Southeast Asian Nations
ASM	Akademi Sains Malaysia
ASTHRDP	Accelerated Science and Technology Human Resource Development Program
AUV	Autonomous Underwater Vehicle
BARMM	Bangsamoro Autonomous Region in Muslim Mindanao
BFAR-NFRDI	Bureau of Fisheries and Aquatic Resources - National Fisheries Research and Development Institute
BIST	Business Innovation through Science and Technology

Acronym	Meaning
BoC	Bureau of Customs
BOL	Bangsamoro Organic Law
BPO	Business Process Outsourcing
BSGC	Budgetary Support to Government Corporations
CARP	Comprehensive Agrarian Reform Program
CAT scans or CT scans	Computerized Axial Tomography
CCC	Climate Change Commission
CCGT	Close Cycle Gas-turbine
CHED	Commission on Higher Education
CHW	Community health worker
CITES	Convention on International Trade in Endangered Species
cleantech	Clean Technology
CLSU	Central Luzon State University
CoE	College of Engineering
COVID-19	Coronavirus Disease 2019
CRADLE	Collaborative Research and Development to Leverage Philippine Economy
CS	College of Science
CW	Constructed Wetlands
DA	Department of Agriculture
DAP	Development Academy of the Philippines
DATOS	Remote Sensing and Data Science
DECS	Digital Ecosystem
DENR	Department of Environment and Natural Resources
DepEd	Department of Education
DICT	Department of Information and Communications Technology
DILG	Department of Interior and Local Government

LIST OF ACRONYMS

Acronym	Meaning
DLSU	De La Salle University
DND	Department of National Defense
DOE	Department of Energy
DOF	Department of Finance
DOH	Department of Health
DOLE	Department of Labor and Employment
DOST	Department of Science and Technology
DOTr	Department of Transportation
DPWH	Department of Public Works and Highways
DRR CCA	Disaster Risk Reduction and Climate Change Adaptation
DT	Digital Twin
DTE	Digitally Transformed Entity
DTI	Department of Trade and Industry
DTP	Digital Teaching Platform
DX	Digital Transformation
ECS	Extended Continental Shelf
EEZ	Exclusive Economic Zone
EGDI	E-government Development Index
EGDI	E-government Development Index
EMB	Environmental Management Bureau
EMO	Earth and Marine Observation
EOS	Earth Observing Systems
EPI	E-participation index
EPIMB	Electric Power Industry Management Bureau
EPIRA	Electric Power Industry Reform Act of 2001
ERD	Energy Recovery Devices
ESA	European Space Agency
ESEP	Engineering Science and Education Project
ESET	Emerging Science, Engineering and Technology
EST	Environmentally Sound Technology
EU	European Union
FAO	Food and Agricultural Organization
FEC	Filipinovation Entrepreneurship Corps
FEPP	Future Earth Philippines Program
FGD	Focus Group Discussion

Acronym	Meaning
FIC	Fully Immunized Child
FIES	Family Income and Expenditure Survey
FIRe	Fourth Industrial Revolution
FMB	Forest Management Bureau
FO	Forward Osmosis
FSTPs	Foreign/Filipino Science and Technology Professionals/ Practitioners
GAA	General Appropriations Act also known as National Budget
GCI	Global Competitiveness Index
GCR	Global Competitiveness Report
GDP	Gross Domestic Product
GDP	Gross Domestic Product
GFAs	Government Funding Agencies
GHG	Greenhouse Gas
GII	Global Innovation Index
GIS	Geographic Information System
GMO	Genetically modified organism
GPG	Global Public Good
GRDP	Gross Regional Domestic Product
GRP	Government Regulatory Processes
Gt	Gigaton
GVA	Gross Value Added
HAPS	High Altitude Platform Systems
HDI	Human Development Index
HEI	Higher Education Institution
HIC	High Income Country
HIT	Health Information Technology
HIV/AIDS	Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome
HNRDA	Harmonized National Research and Development Agenda
HPSR	Health Policy and Systems Research
HRH	Human Resources for Health
IAS	Immersive Authentic Simulation
ICM	Integrated Coastal Management
ICT	Information and Communications Technology
IEC	Information, Education, and Communication
IEEE	Institute of Electrical and Electronics Engineers

Acronym	Meaning
IFPRI	International Food Policy Research Institute
IMPACT	Intellectual Property Management Program for Academic Institutions Commercializing Technologies
IMTA	Integrated multi-trophic aquaculture
INSEAD	Institut Européen d'Administration des Affaires
INSEAD	Institut Européen d'Administration des Affaires
IOM	Integrated Ocean Management
IoT	Internet of Things
IP	Intellectual Property
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
ISA	International Seabed Authority
ISIS	Islamic State of Iraq and Syria
ISO	International Organization for Standardization
IT	Information Technology
ITPS	Intergovernmental Technical Panel on Soils
ITS	Intelligent Transport Systems
ITU	International Telecommunications Union
IUUF	Illegal, Unregulated and Unreported Fishing
IWB	Interactive Whiteboard
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
JRC	Joint Research Centre
K-12	From kindergarten to 12th grade
KAPs	Knowledge to Action Programs
KIG	Kalayaan Island Group
KISTEP	Korean Institute of Science and Technology Policy
kph	kilometers per hour
LAN	Local Area Network
LED	Light Emitting Diode
LGU	Local Government Unit
LIDAR	Light Detection and Ranging (Technology)

Acronym	Meaning
LMIC	Low- and Middle-Income Country
LMS	Learning Management System
maglev	magnetic levitation
MDG	Millennium Development Goal
MF	Microfiltration
MGI	McKinsey Global Institute
MGR	Marine Genetic Resources
MILF	Moro Islamic Liberation Front
MNR	Ministry of Natural Resources
MODIS	Moderate Resolution Imaging Spectroradiometer
MPA or MPAs	Marine Protected Areas
MR	Mixed Reality
MRA	Mutual Recognition Agreements
MRP	Malnutrition Reduction Program
MSME	Micro, Small, and Medium Enterprise
MSP	Marine Spatial Planning
MSW	Municipal Solid Wastes
MSY	Maximum Sustainable Yield
MTOE	Millions of Tonnes of Oil Equivalent
MVNO	Mobile Virtual Network Operator
NAPC	National Anti-Poverty Commission
NASA	National Aeronautics and Space Administration
NAST PHL	National Academy of Science and Technology, Philippines
NCD	Non-Communicable Disease
NCR	National Capital Region
NDRRMC	National Disaster Risk Reduction and Management Council
NEDA	National Economic and Development Authority
NF	Nanofiltration
NGDLE	Next Generation Digital Learning Environment
NGO	National Government Organization
NGP	National Greening Program
NIBRA	National Integrated Basic Research Agenda
NICER	Niche Centers in the Regions for Research and Development
NISMED	National Institute for Science and Mathematics Education Development

LIST OF ACRONYMS

Acronym	Meaning
NISTEP	National Institute of Science and Technology Policy
NLP	Natural Language Processing
NOAH	Nationwide Operational Assessment of Hazards
NPHW	Non-Physician Health Workforce
NQI	National Quality Infrastructure
NRCP	National Research Council of the Philippines
NSTVET	National System of Technical Vocational Education and Training
NTFP	Non-Timber Forest Product
NWRB	National Water Resources Board
OCGT	Open Cycle Gas-turbine
ODA	Overseas Development Assistance
OECD	Organization for Economic Cooperation and Development
OTEC	Ocean Thermal Energy Conversion
PAAC	Presidential Anti-Corruption Commission
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
PCC	Philippine Carabao Center
PCHRD	Philippine Council for Health Research and Development
PCIEERD	Philippine Council for Industry, Energy and Emerging Technology Research and Development.
PCP	Primary Care Physician
PDP	Philippine Development Plan
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PGUIRR	Philippine Government University Industry Research Roundtable
PHC	Primary Health Care
PHD	Planetary Health Diet
PHILRICE	Philippine Rice Research Institute
PhilSA	Philippine Space Agency
Phil-WAVES	Philippine Wealth Accounting and the Valuation of Ecosystem Services
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PHNET	Philippine Network Foundation, Inc.
PIA	Philippine Innovation Act

Acronym	Meaning
PISA	Program for International Student Assessment
PMB	Philippine Mobile Belt
POPCEN	Census of Population
PPH	Precision Public Health
PRO	Pressure Retarded Osmosis
PSA	Philippine Statistics Authority
QS	Quacquarelli Symonds
R&D	Research and Development
RA	Republic Act
RDF	Refuse-derived fuel
RDI	Research and development institutions
RDLead	Research and Development Leadership
RE	Renewable Energy
RFID	Radio-Frequency Identification
RIIC	Regional Inclusive Innovation Center
RO	Reverse Osmosis
ROV	Remotely operated underwater vehicle
RPA	Robotic Process Automation
RPS	Renewable Portfolio Standard
RSE	Research Engineers and Scientist
RSM	Regional Scientific Meeting
S&T	Science and Technology
S4C	Science for Change
SDG	Sustainable Development Goal
SDN	Software-Defined Networking
SEAMEO-INNOTECH	Southeast Asian Ministers of Education Organization - Regional Center for Educational Innovation and Technology
SEC	Specific Energy Consumption
SEEA	UN System of Environmental-Economic Accounting
SETUP	Small Enterprise Technology Upgrading Program
SK	Sangguniang Kabataan
SLR	Sea Level Rise
SMEs	Small and Medium Enterprises
SOC	Soil Organic Carbon
SRA	Social Reform Agenda
SST	Sea Surface Temperature

Acronym	Meaning
SSTA	Space and Science and Technology Applications
STAMINA4Space Program	Sustained Support for Local Space Technology and Applications Mastery, Innovation and Advancement program
STE schools	Science, Technology and Engineering-Implementing schools
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology, and Innovation
SUC	State Universities and College
SWOT	Strengths, Weaknesses, Opportunities, and Threats
SWRO	sea water reverse osmosis
TELCO	Telephony and Data Communications Provider
TESDA	Technical Education and Skills Development Authority
TFEC	Total Final Energy Consumption
THE	Times Higher Education
TISEC	Tidal Instream Energy Conversion
TOD	transit-oriented development
TOWS	Threats, Opportunities, Weaknesses, and Strengths
TPES	Total Primary Energy Supply
UAV or UAVs	Unmanned Aerial Vehicles
UF	Ultrafiltration
UHC	Universal Health Care
UN	United Nations
UN ECOSOC	United Nations Economic and Social Council
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNCLOS	United Nations Convention on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UP	University of the Philippines
USAID	United States Agency for International Government
USD	US Dollars
UST	University of Santo Tomas

Acronym	Meaning
UV	Ultraviolet (rays)
VOC	Volatile Organic Compound
VR	Virtual Reality
WEF	World Economic Forum
WEP	Western Equatorial Pacific
WESM	Wholesale Electricity Spot Market
WFH	Work from Home
WFO	Work from Office
WHO	World Health Organization
WiFi	Wireless Fidelity
WIPO	World Intellectual Property Organization
WWT	Wastewater Treatment

EXECUTIVE SUMMARY

Towards a Prosperous, Archipelagic, Maritime Nation

As the Philippines moves into the future, it faces challenges both old and new: the country continues to struggle with poverty alleviation even as it faces the challenges of the ongoing COVID-19 pandemic as well as the looming threats of climate change and regional geopolitics, among others. In 2018 alone, it is estimated that close to one out of every five Filipinos lives below the poverty line. Meanwhile, the country's population is expected to burgeon from some 110 million people as of this writing to over 144 million by 2050. Science, technology, and innovation (STI) will be fundamental in addressing these complex and interrelated problems—hence the need for this PAGTANAW 2050.

This Foresight underscores the archipelagic nature of our country and its implications and potentials for development: with 220 million hectares of marine environment and 29.8 million hectares of land, the Philippines' many societies and cultures have been mostly coastal in nature. Moreover, some 60% of the population resides along the coast, with a long history of use of the marine environment and resources. The observations, aspirations, and recommendations contained in this Foresight are firmly grounded on a shared vision of a Prosperous, Archipelagic, Maritime Nation.

The full measure of the intellectual weight of the National Academy of Science and Technology's experts, thought leaders, and allies across various fields has been brought to bear on this Foresight. We are thankful for the copious time that they volunteered and their in-depth participation in the many phases of this project—from comprehensive reference scanning and the Delphi method, to focused group discussions and scenario planning, and beyond. From these emerged many diverse perspectives, trends, opportunities, and particularly valuable insights on STI at both the national and international levels.

Marine Resources, Maritime Heritage, and Science, Technology, and Innovation

We look back on our long maritime history and close relationship with the marine environment, from our precolonial balangays of centuries ago to today, with respect and an eye to the future. STI empowers our maritime traditions to encompass both the old and new: for example, a multi-hull "trimaran" boat, inspired by traditional designs yet powered by hybrid sources, was recently designed and built locally for passenger and cargo transport. Such innovations, informed by local culture and traditions but with modernity and the future in mind, should be further encouraged and supported towards the realization of a comprehensive Philippine Nautical Highway. The judicious planning and development of land, coastal, and marine resources through STI can facilitate the economical and efficient operation of shipbuilding and other industries. Further, our vast marine waters lend themselves perfectly to renewable energy initiatives that tap into waves, tides, thermal vents, and other natural marine resources. And, though our societies have progressed over the centuries, our vulnerabilities have only escalated: fisheries, aquaculture, and coastal industries are beset by increasingly severe seasonal typhoons. Climate change impacts such as stronger winds, excessive rainfall, and ocean acidification have made things worse. This situation is further aggravated by physical impairments from land reclamation and from chemical and solid waste pollution from watersheds. These problems call for integrated and harmonious planning and development via a "Highlands-to-Oceans" approach to land, coastal, and marine management, which should be a top government priority. The modernization of Philippine fisheries and aquaculture and the proper maintenance of Marine Protected Areas, are extremely potent in increasing marine productivity and the well-being of marine biodiversity. For example, our Marine Genetic Resources (MGRs)— situated as they are within the Coral Triangle, a global center of marine biodiversity—can potentially produce novel biologically active compounds for various pharmaceutical and other purposes. MGRs from marine organisms like bacteria, fungi, algae, other plants, and animals should thus be screened, studied, and isolated for drugs that have anti-pain, anti-infection, and anti-cancer effects. Further, while the extraction of minerals and other materials from our seas could be profitable and gainful if sustainably managed, other benefits and costs—to both the public and private sector—should be factored into the calculus of their exploitation.

The Philippines also boasts almost a hundred seaports—all of which, though invaluable to society and the economy, could still be improved and modernized in order to make them disaster resilient. We also need to strengthen national maritime standards and compliance with regional and global maritime agreements and international maritime conventions; and embark on the development of a Coastal and Inland Waterways Transport System and a Maritime Innovation and Knowledge Center, among others.

In this Foresight, we have framed the nation's aspirations firmly within the context of our natural and physical endowments—an archipelago with abundant marine resources—as well as our shared Filipino values and skill sets, and other potentials. This STI Foresight builds on current national aspirations and goals as outlined in the 1987 Philippine Constitution, AmBisyon Natin 2040, the Philippine Development Plans, the United Nations (UN) Sustainable Development Goals (SDGs), and the DOST Harmonized National Research and Development Agenda (HNRDA).

Key Operational Areas, Clusters, and Foresighting

At the core of this Foresight are 12 key operational areas, outlined below, which can enable the realization of our societal aspirations through a unified STI agenda:

Blue Economy. The "blue economy" approach is imperative in the Philippines, an archipelagic country with territorial seas that are twice the size of its total land area. Scientific and technological innovations are expected to play a crucial role in the preparation and implementation of a comprehensive action plan for a National Coast and Ocean Strategy.

Governance. Having effective and well-governed institutions are essential to establishing an environment of high rates of investment and improved workforce performance in both the public and private sectors. Strategic technologies can be harnessed for both the government and private sectors to provide quality services, minimize human errors, reduce unreasonable bureaucratic procedures and unnecessary expense, and ultimately achieve administrative efficiency and timely response.

Business and Trade. While the Philippines has yet to establish a track record of translating scientific research into commercial products, the prospects can be improved dramatically by considering the business community's fundamental capacity as both beneficiary and enabler of innovation. In particular, we should provide a level playing field for our agriculture, industry and service sectors whose processes are especially friendly to innovation and research and development (R&D). However, this will not happen if the high cost of doing business—which includes the cost of energy—stemming from the poverty of public goods is allowed to persist.

Digital Technology/Information and Communications Technology. In this section, information and communications technology (ICT) is seen as a linchpin for achieving proficiency in STI in the Philippines. The full realization of the benefits of ICT will necessitate a shift towards a robust and accessible Digital Ecosystem, in which Digitally Transformed entities interact with each other, mutually benefit each other, and promote the greater good. Technologies like blockchain, cognitive systems, robotics, and quantum computing including last-mile connectivity to serve users in rural and remote areas are required of this ecosystem.

Science Education and Talent Retention. The importance of the Science, Technology, Engineering, and Mathematics (STEM) system of education in producing competitive STEM talent in the Philippines is vital in enhancing, maintaining, and monitoring the knowledge infrastructure in STEM. We need to adopt new out-of-the-box pedagogies that emphasize learning by doing.

Food Security and Nutrition. This operational area highlights the ability of agriculture to increase and diversify production towards the improved nutritional status of the population through new and science-based food system paradigms. In order to achieve desired nutritional outcomes, a sustainable food system should be characterized by green and inclusive growth, economic and social progress, and resilience to multiple risks.

Health Systems. Foresighting the Philippines' health STI is anchored in achieving an efficiently working and properly funded Universal Health Care Program, which addresses needs that are real, palpable, and which immediately improve human lives. At the moment of writing this Foresight, the Philippines' response is focused towards managing the COVID-19 pandemic. Many of the health system technologies accelerated by the pandemic are quite useful for strengthening the healthcare delivery system.

Energy. Since the Philippines is dependent on imported fossil fuel for its energy needs and the energy sector is among the major contributors to greenhouse gas emissions and climate change, it is essential for the country to transition to clean and affordable energy technologies to meet future needs. Priority should be given to solar, wind, and ocean waves energy systems, energy storage, smart grids and networks, biofuels, and energy from wastes.

Water. Water resources, water uses, and regional water quality, demand and supply in the Philippines must be managed with regard to their use for domestic water supply, irrigation, flood control, power generation, and pollution control. Clean technologies will be adopted to improve the delivery of affordable clean water, minimize or prevent the production of wastewater effluents, and reduce the cost of water and wastewater treatment.

Environment and Climate Change. The Philippines is a hazard-prone country and periodically suffers from extreme weather conditions, earthquakes, volcano eruptions, and other natural hazards. It is also one of the countries that are most vulnerable and at risk to climate change. Consistent with Goal 13 of the United

Nations' Sustainable Development Goals, the Philippines must adopt global and local actions to combat climate change and manage its impacts by strengthening resilience and adaptive capacity to climate-related hazards and other natural hazards.

Shelter, Transportation, and Other Infrastructure. Secure shelter and good transport facilities are minimum basic needs that are fundamental to what Filipinos aspire for as "maginhawang buhay" (comfortable life) and "panatag na buhay" (secure life), as discussed in AmBisyon Natin 2040 and which still remains relevant within the extended 30-year timeframe of the Foresight. Considering the archipelagic setting and maritime nature of the country, the national aspiration to balance urban and rural development can only be achieved through the improvement of ports, roll-on-roll-off facilities, expressway and road networks, and public transport, coupled with a strategic combination of various water, land, and air transportation modes. Shelter is needed in different forms as residence, refuge, and building as a vital component in organizing smart communities in both urban and rural settings.

Space Exploration. Space-based technologies have important applications in communications, weather forecasting, disaster management, natural resources and land use management, and in monitoring the environment. Current upstream and downstream space initiatives and future plans on space technologies must continue to be enhanced.

To facilitate the foresighting process, the above operational areas were grouped into four clusters that underscore their interrelatedness and interconnectivity: **Food, Nutrition, and Health; Water and Energy; Environment and Space Exploration; and Built Environments.** Over and above these clusters, the operational areas of Digital Technology/ICT, Blue Economy, Business and Trade, Climate Change, Governance, and Science Education and Talent Retention are considered critical influencers and enablers that cut across all operational areas.

The "Blue Economy" is an overarching operational area that highlights the Philippines' inherently archipelagic nature and resources, pointing towards the sustainable use of marine resources—living and non-living—for the improvement of people's livelihoods while preserving the overall health of our marine ecosystems.

'Black Swans' and Hope for the Future

Integrative and future-responsive resilience is fundamental to this Foresight, as it should be for all development plans now and into perpetuity. Particularly relevant to this Foresight is the careful consideration and development of upcoming STI for the provision of goods and services; and land, coastal, and marine planning. This proactive stance is vital not just for anticipated crises such as typhoons and earthquakes, but also for unforeseen crises such as pandemic outbreaks and threats to water safety and security—all of which can all too easily stem from the mismanagement of marine and other resources. Hence, we include in this Foresight a cautionary but optimistic note on **Black Swans**: the threat of unpredictable future shocks—whether truly exogenous or stemming from the country's still developing institutional framework, human capital, and innovation capacity—can be subverted into positive drivers and opportunities: the proper development and implementation of plans to meet long-term integrative goals can do this.

In this regard, it is imperative to have proper governance at all levels and a whole-of-government approach anchored in STI and doing away with "business as usual" approaches at every turn. This necessitates a comprehensive and iterative review of laws, policies, and guidelines, so as to eliminate gaps, contradictions, and redundancies on the way to inclusive Philippine prosperity that makes full sustainable use of our natural endowments.

Strategically Mapping the Future

This STI Foresight would be incomplete without an **STI Roadmap** to guide national development toward our preferred future. This unified and integrated map can be broken down into four complementary sub-maps—one for each of the previously-mentioned technology clusters—that visually trace the foresighted trajectories of the enablers, drivers, and opportunities that are seen to shape Philippine STI for the next three decades.

Given the current pandemic, the Food, Nutrition, and Health map highlights the present emphasis on harnessing technologies towards providing universal healthcare and ensuring affordable and nutritious food through a transformation of food systems practices; artificial intelligence and ICT are seen to eventually play dominant roles in decision-making for health and nutrition. The roadmap for Energy and Water sees the emerging dominance of low-cost, large-scale renewable energy technologies and sources. Meanwhile, the map for Environment and Space Exploration outlays the path towards an improved capability to mitigate or altogether prevent natural hazards and disasters by utilizing appropriate, adaptive, and clean/green technologies; space technologies will play a key role in this regard, for monitoring large-scale patterns for assessing climate resiliency and environmental protection. Lastly, the Built Environments map plots the evolution of work and living spaces through the measured adoption of construction- and transportation-related technologies, such as smart materials and electric vehicles, all of which will be interconnected via ICT such as the Internet of Things and virtual/augmented reality.

Ultimately, the development of a globally-competitive Philippine knowledge economy with a maritime base will enable the Philippines to finally break out of its stagnation behind more scientifically-advanced nations, allowing it to grow from a mere service economy into the Prosperous, Archipelagic, Maritime Nation, united and inclusive as it was always meant to be.

SECTION 1

The Making of the 30-Year Science, Technology, and Innovation Foresight and Strategic Plan

SECTION 1.1
THE SCIENCE, TECHNOLOGY, AND INNOVATION FORESIGHT FRAMEWORK

A Foresight, as defined by the European Commission (2002) is "the application of systematic, participatory, future intelligence gathering, and medium-to-long-term vision-building processes to informing present-day decisions and mobilizing joint actions. It brings together key agents of change and various sources of knowledge in order to develop strategic visions and anticipatory intelligence."

With this in mind, the National Academy of Science and Technology, Philippines (NAST PHL) undertook PAGTANAW 2050, a foresight project consisting of a Philippine-focused science, technology, and innovation (STI) strategic plans and roadmaps covering a period of 30 years from 2019-2050.

United and Inclusive, Prosperous, and Sustainable Archipelagic, Maritime Nation

This framework builds on aspirations and initiatives expressed in the 1987 Philippine Constitution, the past and present Philippine Development Plans, the United Nations (UN) Sustainable Development Goals (SDG) 2015–2030, the Department of Science and Technology (DOST) Harmonized National Research and Development Agenda, and AmBisyon Natin 2040. Further adjustments have been made in the wake of the COVID-19 pandemic and its impact on the nation's socioeconomic and political condition.

The aspirations embodied in the aforementioned references can be achieved by actively building on our nation's archipelagic resources and extensive maritime heritage, even as we diplomatically assert our rights over our surrounding marine environment. Such an archipelagic, maritime nation should care for its citizens by fostering unity, inclusivity, prosperity, and sustainability through STI.

The objectives of this STI Foresight are as follows:

- To present an insightful review of key trends, needs, and gaps in STI as it relates to the inclusive growth and competitiveness of the Philippines.
- To propose a 30-year strategic plan using available data and information along with key targets/indicators, delivery mechanisms, and policies gathered from various stakeholders.
- To establish an STI framework and 30-year strategic plan by integrating transformative thinking, planning, monitoring, and inclusive implementation towards an STI supported and encultured Philippines.

The Foresight Process

The Foresight project involves participatory and inclusive ideation and validation to explore diverse perspectives at the national and international levels. A schematic overview of the NAST PHL STI Foresight Framework is shown in Figure 1.1_1. A more detailed representation of expected Inputs and the Outputs is in Figure 1.1_2.

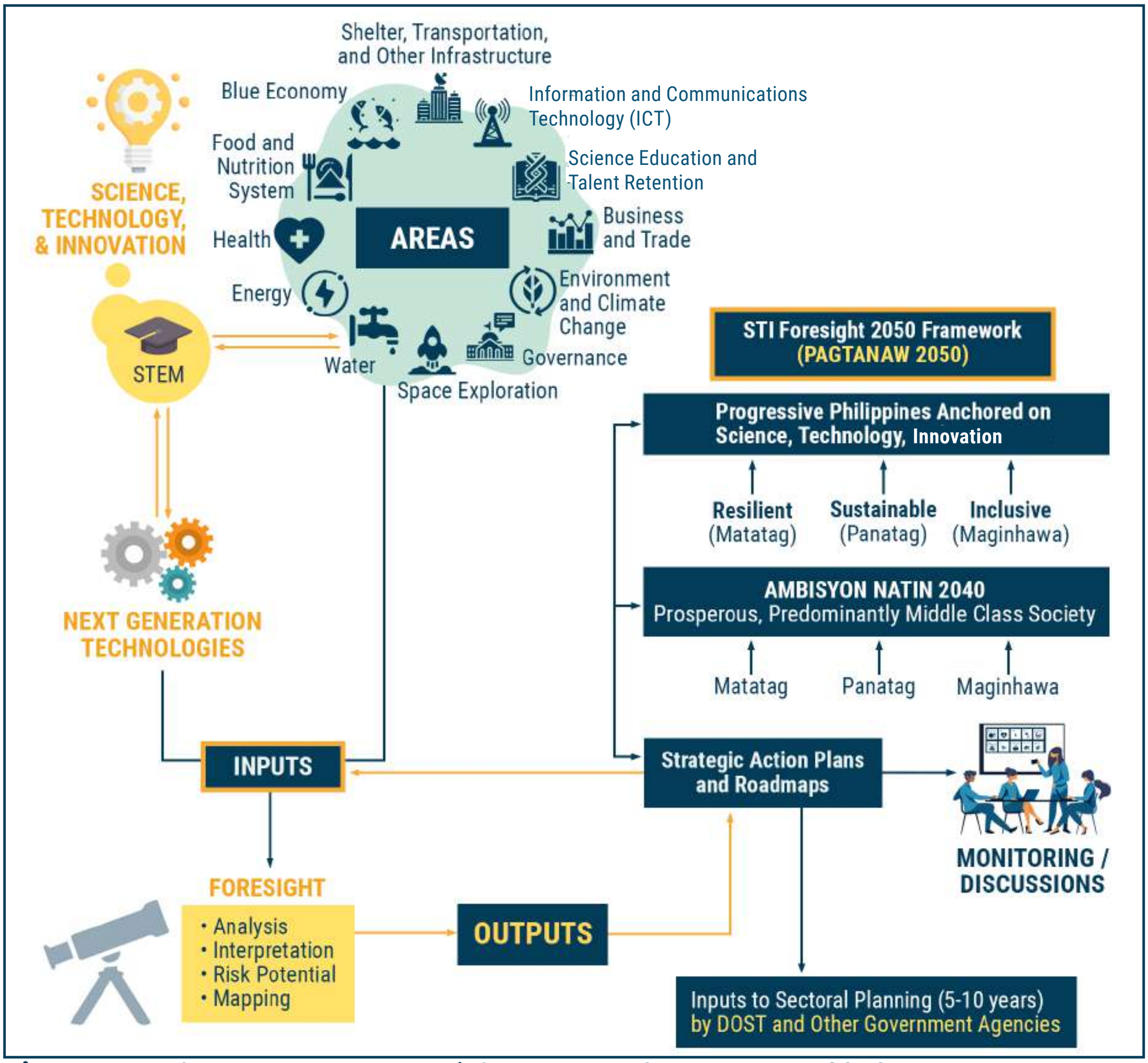


Figure 1.1_1. The NAST PHL STI Foresight Framework: PAGTANAW 2050

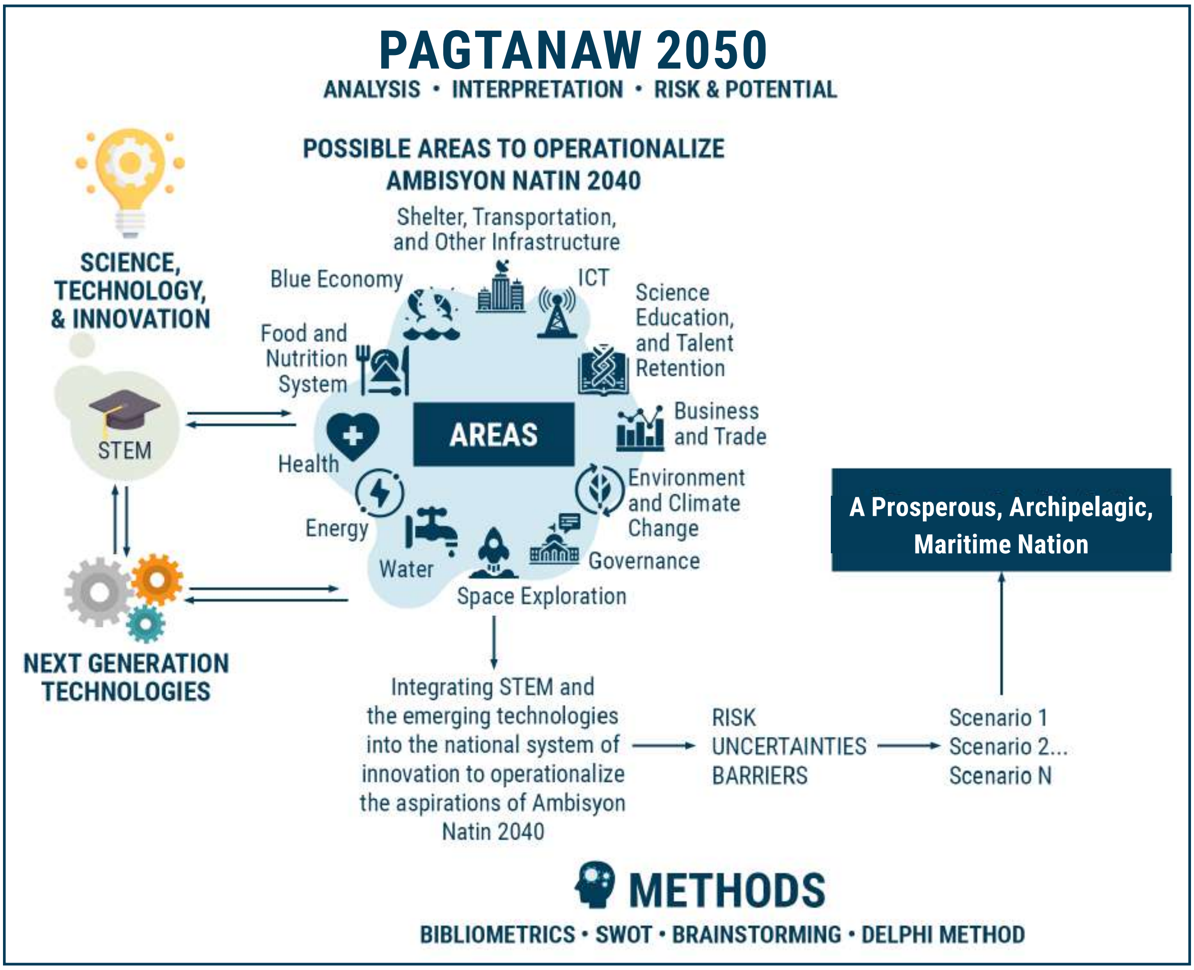


Figure 1.1_2. Inputs and Outputs of the NAST PHL STI Foresight Framework: PAGTANAW 2050

The proposed inputs and outputs herein are initial listings and may undergo refinement and modification as the foresight exercise progresses through the years. It is thus important to be able to determine the needs and trends, opportunities, and drivers of change.

The inputs (Fig. 1.1_1 and Fig. 1.1_2) shall consist of the present and next-generation tools that Science, Technology, Engineering, and Mathematics (STEM) and Emerging Technologies may provide to address the operational areas by exploiting the synergies across technologies that will best contribute to the realization of the aspirations in the following references:

- The 1987 Constitution of the Republic of the Philippines
- NEDA Report on AmBisyon Natin 2040 (NEDA 2016)
- Philippine Development Plans (NEDA 1987, 1993, 1999, 2004, 2011, 2017)
- RA 8425: An Act Institutionalizing the Social Reform and Poverty Alleviation Program, Creating for the Purpose the National Anti-Poverty Commission, Defining Its Powers and Functions, and for Other Purposes (signed into law on 28 July 1997). This law defines the components of the Minimum Basic Needs.
- DOST Harmonized National Research and Development Agenda (DOST 2016)
- UN Sustainable Development Goals 2015-2030

The outputs indicated in Figure 1.1_1 and Figure 1.1_2 were the results of several data gathering and analytical methods. First, megatrends and other relevant information on Philippine STI and foresight methods were culled following a thorough review of available bibliometric sources. This was followed by a series of workshops and meetings (from January 2020 to March 2021) with experts and relevant stakeholders that considered futures thinking/foresight methodology for Philippine STI and strategic, long-term, comprehensive policy and action plans for inclusive development, security, and governance.

The 2020 NAST PHL Annual Scientific Meeting (ASM) and Regional Scientific Meetings (RSM) were of particular importance to this Foresight in that they solicited and collated the perspectives of the broad scope of researchers and topic experts that comprise the science community. Close to a thousand participants attended each two-day meeting, which served as the initial stakeholders' consultation on the operational areas of the STI foresight. Paper presentations and commissioned papers from the ASM and RSMs served as sources of data and information and recommendations for the STI Foresight.

Strengths, Weaknesses, Opportunities, and Threats (SWOT) & Threats, Opportunities, Weaknesses, and Strengths (TOWS) Analysis. A SWOT and TOWS workshop was undertaken involving the problem tree analysis wherein the experts enumerated and discussed the causes (root), problems (trunk), and effects or consequences (branches) for the identified science and technology (S&T) areas. The SWOT paved the way for the internal and external analyses of the National Innovation System wherein internal analysis was done by enumerating the system's strengths and weaknesses. External analysis was made by reviewing political, economic, environmental, socio-cultural, technological, and legal factors that could pose threats or provide opportunities. Through TOWS, experts managed to determine ways to use the strengths of the STI community to actualize opportunities and cope with threats. Similarly, they also came up with ways to use opportunities in minimizing weaknesses and use threats in correcting weaknesses.

Delphi Survey. A two-round Delphi survey was conducted to arrive at a consensus on the following:

(1) Expected changes in aspirations outlined in AmBisyon Natin 2040 due to COVID-19 pandemic
(2) Sociocultural, technological, economic, environmental, and political megatrends for consideration in the foresight
(3) Expected black swans or disruptions as Filipinos journey to 2050
(4) Additional areas for consideration in the foresight
(5) Perceived areas of current strength in Philippine STI
(6) Additional areas in the future that Philippine STI should be leading in
(7) Private and public institutional changes to enhance the role of STI in development and the lives of Filipinos
(8) Talent development and retention in STI

(9) Harnessing STI in asserting our sovereignty and identity as a maritime nation
(10) Public investments and interventions in STI to reduce poverty or the conditions associated with poverty

A total of 243 respondents answered the first round of the Delphi survey, while 206 managed to participate in the second round. Respondents came from various academic institutions, civil society, government agencies, government-owned and controlled corporations, government think tanks, industry, international organizations, non-government organizations, professional organizations, and research and development (R&D) institutions (Table 1.1_1).

Table 1.1_1. Profiles of Delphi Survey Respondents by Institution

Round 1 Respondents		Round 2 Respondents	
Affiliation	Frequency	Affiliation	Frequency
NAST PHL	46	NAST PHL	33
Outstanding Young Scientists, Inc.	18	Academe	97
Higher Education Institutions	40	Executive Department	8
DOST	33	Industry	9
Philippine American Academy of Science and Engineering	37	International Organizations	3
Philippine Science High School	12	Non-Government Agencies/Organizations	45
Professional Organizations in the Basic Sciences	4	Others	7
		Government Think Tanks	1
		Government Think Tanks	2
Private Business/Industries	7	Professional Organizations	1
RDI	28	RDI	1
STEM Institutes/Organizations	8	Government-Owned and Controlled Corporations	1
Food Industry	2	Law	1
Unknown	4	Civil Society	1
Others	4		
Total	**243**	**Total**	**202**

Scenario Planning. In addition to the Delphi survey, the NAST PHL also conducted scenario planning exercises for major STI operational areas, which were then grouped into clusters based on their interrelatedness and interactions (see Section 6.1), to wit:

Cluster I: Health, Food Systems, Nutrition
Cluster II: Energy and Water
Cluster III: Environment and Climate Change and Space Exploration
Cluster IV: Shelter, Transportation, and Other Infrastructure

In the said workshop, participants came up with a futures triangle, wherein the pull factors of the future, push factors of the present, and weight of the past were scrutinized. Drivers of change and potential threats were also mapped in the process. Four scenarios were discussed: disowned futures, outlier futures, preferred futures, and integrated futures. The disowned futures scenario showed more dysfunctions and unintended consequences and was considered to result in an unsustainable and non-resilient future, Meanwhile, the outlier futures scenario was described as a "strange, unusual, and improbable" but somewhat "beautiful" future. The preferred scenario was the one that the participants looked forward to by 2050. After discussing these futures scenarios, the preferred and integrated futures scenarios were used to guide the causal layered analysis wherein experts crafted a hypothetical news headline and named underlying systems, worldviews, myths and metaphors governing the clusters. The last step in the scenario planning was the backcasting. This was necessary as this required the experts to delineate steps that would help the country achieve the integrated futures scenario per cluster.

SECTION 1.2
THE SCIENCE, TECHNOLOGY, AND INNOVATION FORESIGHT OF OTHER COUNTRIES

The quality and impact of decision-making are greatly improved by going through an exercise in foresight. Foresight serves as a beacon light in the preparation of strategies and prepares institutions and individuals to react to the challenges that are yet to come (EFP 2010).

This section will analyze the foresight documents of Japan, South Korea, and Malaysia. Due to constraints in the availability of the above reports in English, we shall cover only the 10th Science and Technology (S&T) Foresight of Japan (NISTEP 2015), the 5th Science and Technology Foresight (2016-2040) of South Korea (KISTEP 2017), and the Science and Technology Foresight Malaysia 2050 (ASM 2017).

Basis of the Foresight

All three S&T foresight reports were initiated and implemented by the governments of the countries concerned. Japan has been engaged in S&T foresight since 1971 and every five years thereafter, under the leadership of the Science and Technology Foresight Center (Japan). For South Korea, their S&T foresight was developed on a five-year interval in compliance with Articles 13 and 22 of the "Framework Act on Science and Technology", while the Malaysian foresight report was derived from the Emerging Science, Engineering &Technology (ESET) Study.

Societal Goals

The foresight reports all start with an assessment of the aspirations of their respective citizenry as indicated in Table 1.2_1. Although they vary in terms of their specific articulation, the reports cover the basic aspects of societal well-being, such as health, food security, access to livelihood opportunities, and concern about the impact of climate change and human activities on the environment.

Methodology

All three foresight exercises used more than one method to gather ideas for their report (Table 1.2_1). The choice of methods regarding the scope of foresight in S&T vary slightly among the three foresight reports. However, the foresight reports of Japan, Korea, and Malaysia all indicated the use of consultations with experts and other stakeholders.

Japan and Korea conducted Delphi surveys and undertook scenario-planning for various topics. Korea used the tipping point method to narrow down their technological choices. Malaysia relied primarily on working groups organized by priority areas, and involved foreign institutions and experts, focusing their discussions on five areas: biotechnology, digital technology, green technology, nanotechnology, and neurotechnology.

The megatrends and uncertainties identified by the three countries can be clustered into the following:

- increasing dominance of the digital age and the disruptive technologies
- climate change
- concern for the impact of man's activities on the environment
- impending global changes in the economic systems
- changing demographics especially the increase of ageing communities
- and the rapid developments in international cooperation

Since all the three reports were written before the COVID-19 pandemic, there is almost no reference to the same, or to the possible recovery activities when the pandemic has been brought under control (Table 1.2_1).

Table 1.2_1. Foresight Reports of Japan, Korea, and Malaysia

Components	Japan (2015) 10th S&T Foresight Plan	Korea (2017) The 5th Science and Technology Foresight (2016-2040)	Malaysia (2017) Science and Technology Foresight Malaysia 2050 Emerging Science, Engineering, & Technology (ESET) Study
Basis	The Technology Foresight Survey has been conducted every five years since 1971, engaging S&T experts in Japan to suggest a future path of technological development in the next 30 years and to contribute to government policy decision-making and decisions on research allocation in S&T. The survey is conducted by the Science and Technology Foresight Center.	Framework Act on Science and Technology Article 13 and Article 22 of the Enforcement Decree of the Framework Act on Science and Technology (Science and Technology Forecasting, etc.)	ESET Study focused on biotechnology, digital technology, green technology, nanotechnology, and neurotechnology.

Table 1.2_1. Continued

Components	Japan (2015) 10th S&T Foresight Plan	Korea (2017) The 5th Science and Technology Foresight (2016-2040)	Malaysia (2017) Science and Technology Foresight Malaysia 2050 Emerging Science, Engineering, & Technology (ESET) Study
Societal Goals/ Aspirations	• Connected society • Knowledge-based and service-oriented society • Healthy long-life society • Sustainable regional society • Manufacturing-based society • Resilient society • Japan in global context	• Responsiveness to changes in future social demand • Development of science and technology • Social Infrastructure, e.g., nuclear safety, safety infrastructure • Ecosystem and environment friendliness, e.g., weaponization of food, ecosystem change due to climate change • Transportation and robotics, e.g., unmanned vehicles, home service robots • Medical and Life, e.g., new infectious diseases, weaponization of vaccines • Manufacturing and convergence, e.g., new materials, transition from traditional manufacturing • Information and Communication e.g., cybercrime, educational system reform	• Make Malaysia a powerhouse for high value chain activities in Electrical and Electronics sector • Make Malaysia a regional leader in Agrotechnology and Agribusiness • Make Malaysia a premier global Halal hub • Ensure well-being and health of the people of Malaysia • Accelerate socio-economic transformation leveraging the digital tsunami • Move towards a low waste, resource-efficient society
Methodology	• Visioning • Delphi Survey • Scenario Planning • Evaluation of importance, certainty/uncertainty, non-continuity, morality, international competitiveness, expected year for technology realization and real-world implementation • Challenges/Policy measures	• Brainstorming • Delphi Survey • Horizon scanning • Scenario Planning • Tipping Point Analysis • Social, Technological, Environmental, Economic, and Political (STEEP) analysis	• Working Groups: biotechnology, digitla technology, green technology, nanotechnology, neurotechnology • Horizon scanning and bibliometrics • Surveys • Strategic consultations • Engaged international and Malaysian experts
Megatrends	• Open science and innovation • Data science • Applied use of big data • Support for decision making • Artificial Intelligence • Ethical, legal, and social implications (ELSI) issues • National security and safety, etc. • Cyber-physical system enables new coalescence of humans and machines • Information is automatically analyzed and selected • Aging population • Collaborative start-up • Occupation is free from physical capability like aging and physical disability • New jobs	• Human Empowerment • Innovation through Hyper-connectivity • Deepening Environmental Risk • Intensification of Social Complexity • Reorganization of the Economic System	• Shift in global economic power • Emergence of disruptive technology • Rapid urbanization • Demographic and social change • Climate change • Global risks (extreme weather events, large-scale involuntary migration, natural disaster, terrorist attacks, data fraud or theft).

Table 1.2_1. Continued

Components	Japan (2015) 10th S&T Foresight Plan	Korea (2017) The 5th Science and Technology Foresight (2016-2040)	Malaysia (2017) Science and Technology Foresight Malaysia 2050 Emerging Science, Engineering, & Technology (ESET) Study
Findings/ Recommendations	• Examined 312 items with high importance • Combined scores for uncertainty and discontinuity to extract items within top 10% (30 items) and bottom 10% (30 items) • Global competitiveness to finalize the ranking to top 10% and bottom 10% Thematic scenarios include: • Advanced manufacturing platform • Future co-creating services • Improvement of physical and mental health towards realization of a healthy, longevity society • Maintaining food production and ecosystem services by using regional resources • Resilient social infrastructure to respond to large scale disasters and aging population with fewer children • Energy, environment and resources for a sustainable future • Integrated scenarios form the viewpoint of globalization • S&T topics and thier forecaster year of realization	Indentified 287 technologies that are expected to emerge by 2040 and group them into 18 short-term issues, 14 short-to-mid-term issues, and 8 long-term issues.	• Identified 95 emerging technologies as reference to facilitate discovery of new knowledge, advancing technology platforms and realizing innovation in the form of new products and services and technologies for a harmonious, prosperous and sustainable Malaysia. • Developed timelines into present future (2015-2020), probable future (2021-2035), and possible future (2036-2050).

Findings and Recommendations

Finally, the findings and recommendations of the reports consist primarily of the inventory of technologies that are expected to be developed in response to societal needs and interests. The foresight report of Japan listed 312 technologies of high importance and narrowed its list down to the top and bottom 10%; Korea identified 287 technologies that are expected to be available by 2040, and grouped those into short-term issues, short to medium – term issues and into a very short list of eight long–term issues. Malaysia identified 95 technologies that were finally narrowed down to 25.

The inventory of present and prospective technologies that could respond to the unique societal needs of each of the three countries were gathered into scenarios described in varying degrees of detail, including the list of prioritized technologies expected to form the basis of a time-bound strategic plan for developing and harnessing S&T to serve their needs.

SECTION 1.3
SCIENCE AND TECHNOLOGY INDICATORS ON COMPETITIVENESS AND INNOVATION

World Economic Forum Global Competitiveness Index

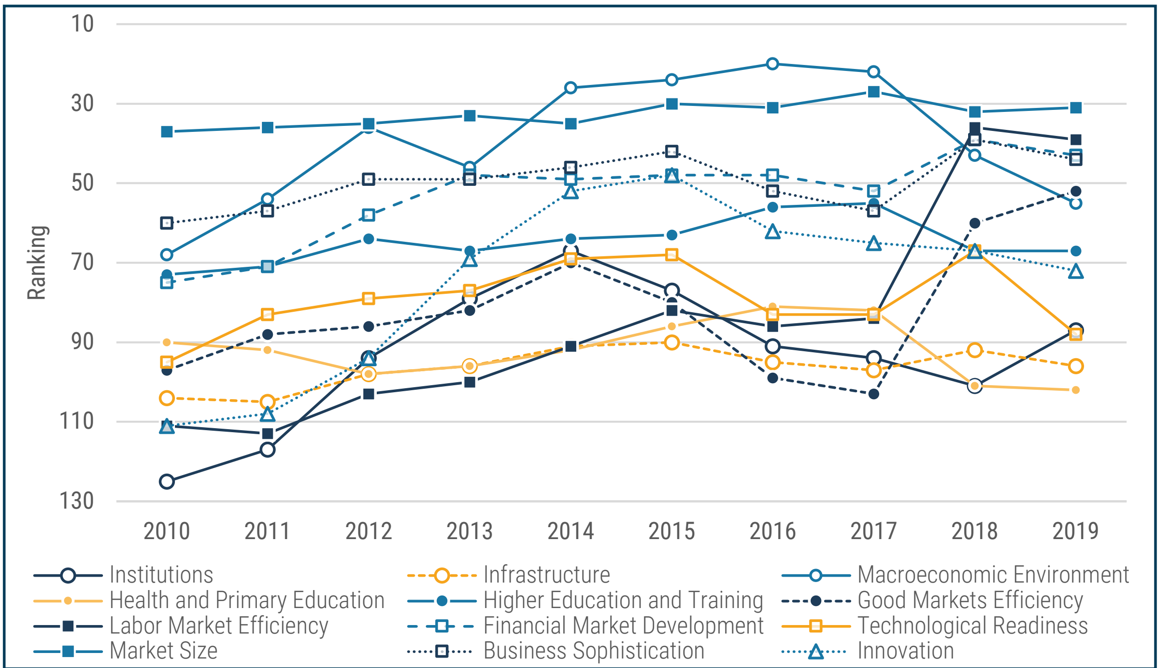
The World Economic Forum (WEF) publishes the Global Competitiveness Report annually to provide insights into the factors and attributes that drive productivity, growth, and human development for over 140 countries. The report also reviews promising policy options to achieve inclusive growth and sustainability. The Global Competitive Index (GCI) is based on the data from international organizations and the WEF's Executive Opinion Survey. The GCI is a comprehensive measure of the microeconomic and macroeconomic foundations of national competitiveness. It uses 12 pillars to leverage points in defining economic success (Dutta et al. 2020).

We observed a steady rise in the Philippines' overall rank from 2010 until 2016 when rankings began to decline (Table 1.3_1). In comparison with other countries in Association of South East Asian Nations (ASEAN), Singapore has remained on the top rank, Malaysia in the top 30, Indonesia and Thailand in the top 40. In 2019, the Philippines ranked 64th out of 141 economies, which was eight ranks lower than the previous year (WEF 2019). Given the effects of the pandemic, results for 2020 are expected to decline.

In the WEF Global Competitiveness Report of 2019, among the 12 pillars of competitiveness (Figure 1.3_1), the three lowest-scored pillars of the Philippines are in Health and Primary Education, Infrastructure, and Technological Readiness. The Philippines appears to have performed well in Market Size, Labor Market Efficiency, and Business Sophistication.

Table 1.3_1. Global Competitiveness Index (GCI) for ASEAN Countries (2010–2019) Overall Rank

Country	Overall Ranking									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Singapore	3	2	2	2	2	2	2	3	2	1
Malaysia	26	21	25	24	20	18	25	23	25	27
Brunei Darussalam	28	28	28	26	-	-	58	46	62	56
Thailand	38	39	38	37	31	32	34	32	38	40
Indonesia	44	46	50	38	34	37	41	36	45	50
Philippines	85	75	65	59	52	47	57	56	56	64
Vietnam	59	65	75	70	68	56	60	55	77	67
Cambodia	109	97	85	88	95	90	89	94	110	106



Pillar	Rank									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Institutions	125	117	94	79	67	77	91	94	101	87
Infrastructure	104	105	98	96	91	90	95	97	92	96
Macroeconomic Environment	68	54	36	46	26	24	20	22	43	55
Health and Primary Education	90	92	98	96	92	86	81	82	101	102
Higher Education and Training	73	71	64	67	64	63	56	55	67	67
Good Markets Efficiency	97	88	86	82	70	80	99	103	60	52
Labor Market Efficiency	111	113	103	100	91	82	86	84	36	39
Financial Market Development	75	71	58	48	49	48	48	52	39	43
Technological Readiness	95	83	79	77	69	68	83	83	67	88
Market Size	37	36	35	33	35	30	31	27	32	31
Business Sophistication	60	57	49	49	46	42	52	57	39	44
Innovation	111	108	94	69	52	48	62	65	67	72

Figure 1.3_1. Ranking and Trend of the Twelve Pillars of Competitiveness of the Philippines

Global Innovation Index

The Global Innovation Index (GII) has been published annually since 2007, a collaboration between Cornell University, Institut Europeen d' Administration des Affaires (INSEAD), and the World Intellectual Property Organization (WIPO). The GII report presents global innovation trends and the innovation performance of 131 economies.

In 2019, out of 131 economies, the Philippines ranked 54th in innovation, besting Indonesia, Brunei Darussalam, and Cambodia among ASEAN countries (Table 1.3_2) (Dutta et al. 2020). In terms of the seven pillars of innovation, the Philippines has shown a consistent rise in the pillars of Knowledge and Technology Outputs and Business Sophistication (Table 1.3_3). A significant improvement in ranking is seen in the pillars of Infrastructure and Creative Outputs.

It is to be noted that in 2019, the Philippines improved its GII significantly, but declined in its ranking in the GCI.

Table 1.3_2. Global Innovation Index (GII) for ASEAN Countries (2010–2019) – Overall Rank

Country	Overall Ranking									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Singapore	7	3	3	8	7	7	6	7	5	8
Malaysia	28	31	32	32	33	32	35	37	25	35
Brunei Darussalam	48	75	53	74	88	-	-	71	67	71
Thailand	60	48	57	57	48	55	52	51	44	43
Vietnam	71	51	76	76	71	52	59	47	45	42
Philippines	76	91	95	90	100	83	74	73	73	54
Indonesia	72	99	100	85	87	97	88	87	85	85
Cambodia	102	111	129	110	106	91	95	101	98	98

Table 1.3_3. Ranking of the Seven Pillars of Innovation for the Philippines (2010-2019)

Pillar	Rank									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Institutions	106	101	132	128	108	102	88	89	93	89
Human Capital and Research	75	116	121	116	121	123	95	95	86	83
Infrastructure	103	68	69	78	94	83	72	72	67	58
Market Sophistication	107	98	106	95	93	101	94	92	100	110
Business Sophistication	81	61	72	96	113	81	74	45	44	32
Knowledge and Technology Outputs	32	76	59	61	68	53	44	42	49	31
Creative Outputs	96	90	108	91	98	101	96	94	92	63

United Nations Conference on Trade and Development Readiness for Frontier Technologies Index

The United Nations Conference on Trade and Development (UNCTAD) (2021) ranked 158 countries in a "Readiness for Frontier Technologies Index" based on the following:

- Level of Information and Communications Technology (ICT) infrastructure
- Skills to adopt and adapt frontier technologies
- Research and development (R&D) activity to adjust and modify frontier technologies for local use
- Ongoing industry activities related to use, adoption and adaptation of frontier technologies
- Access to finance by the private sector to accelerate the use, adoption, and adaptation of frontier technologies

The Philippines ranked 44th, higher than all other ASEAN countries except Malaysia, which ranked 31st. The top five countries, in descending order, were the United States, Switzerland, United Kingdom, Sweden, and Singapore.

The report also notes that the Philippines has a high ranking in industry, reflecting the high levels of foreign direct investments in high-technology manufacturing, particularly electronics. Furthermore, the report cites the existence of pro-business policies; the availability of a skilled, English-speaking workforce; and the presence of a network of economic zones.

Although the top frontier-technology-ready countries are high-income nations, there are outliers: "countries that perform better than their per capita GDPs would suggest," according to the report. This "overperformance" is determined by calculating "the difference between the actual index rankings and the estimated index ranking based on per capita income". The top overperformer is India, with a score of 65, followed by the Philippines with a score of 57. The Ukraine, Vietnam, and China occupy the 3rd, 4th, and 5th spot, respectively.

The Philippines' ranking as the second highest overperforming country in this report augurs well for the nation's ability to take advantage of the window of opportunity to harness frontier technologies towards increasing productivity and creating more industries for employment and livelihood.

Critical Factors in Science and Technology

According to WEF, during the period 2010–2019, four factors were critical to the improvement in the Science and Technology (S&T) domain. These were as follows:

Innovation Capability. The first critical indicator for improving competitiveness is the capacity for innovation (Table 1.3_4), since it is the foundation of S&T development (WEF 2019). The sub-pillars of interaction and diversity, research and development, and commercialization are likewise deemed critical for S&T competitiveness.

Table 1.3_4. Parameters of the WEF GCR Innovation Index for the Philippines

Indicator	Rank									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Company Spending on R&D	85	85	58	51	42	36	44	51	99	102
University-Industry Collaboration in R&D	85	83	79	69	55	55	61	59	27	26
Utility Patents Granted Per Million Population	71	68	83	84	86	85	86	83	80	79
Capacity for Innovation	80	95	86	48	30	33	41	45	49	63
Availability for Scientists and Engineers	96	97	91	87	71	67	78	74	15	9
Quality of Scientific Research Institutions	108	106	102	91	75	69	72	75	71	72
Government Procurement of Advanced Technology Products	129	126	107	85	53	59	74	91	57	56

Innovation capability is seen to be increasing over the last five years. Specifically, the increase is attributed to sub-indices of capacity for innovation, quality of scientific research institutions and its publications, patent applications and developments, international co-inventions, government procurement of advanced technology and products, and availability of workforce such as scientists and engineers—factors that are relevant for science, technology, and innovation (STI).

This indicator is supported by government projects such as the Philippine Innovation Act, whole-of-government approach, and other Department of Science and Technology (DOST)-funded projects (Dutta et al. 2020). The improvement in the number of Research Engineers and Scientists is attributed to two human resource development programs administered by the Science Education Institute of DOST. These are the Engineering Research and Development for Technology and the Accelerated S&T Human Resource Development Program both of which provide scholarships for engineers and scientists to obtain master's and doctoral degrees. Positive results of increased government support can be seen in the significant rise in the Philippines' ranking in the aspects of availability of scientists and engineers, university-industry collaboration in R&D, and government procurement of advanced technology products (Table 1.3_4)

Business Dynamism (previously known as Business Sophistication). The second indicator associated with S&T performance is business dynamism (Table 1.3_3), which belongs to the same Innovation Ecosystem overview as the innovation capability (WEF 2019). Previously known as the Business Sophistication pillar, the Philippines was able to improve its standing because of the sub-pillars of administrative requirements and entrepreneurial culture. Thus, the Philippines is ranked 44th in Business Dynamism, one of the 12 pillars of the 2019 WEF World Competitiveness Index.

S&T development is critical given that this values the framework and resources needed to start businesses and cultural practices such as delegation, risk involvement, and embracing disruptive ideas.

The government embraced the importance of business dynamism with its rollout of Innovative Startup Act, Business Innovation through S&T, and Collaborative Research and Development to Leverage Philippine Economy Program for Industry Program. These projects aim to support local entrepreneur partnerships for STI.

Intellectual Property Rights and ICT Adoption. Better implementation of intellectual property rights and ICT adoption are also crucial to ramping up Philippine S&T's global competitiveness, particularly when exercised in complement with institutionalized government support for innovation and entrepreneurship (DOST 2017), e.g., through RA 10055 or the "Philippine Technology Transfer Act of 2009".

All in all, the above four factors are critical for S&T development and performance. Pro-active efforts in the public and private sector are needed to support and to sustain the development process.

Policy Recommendation

To sustain its improved competitiveness ranking and gains achieved insofar as S&T development is concerned, the Philippines needs to continue to place innovation at the center of the government's economic and development policy, embracing a whole-of-government approach (Uriarte et al. 2013).

SECTION 1.4
TIMES HIGHER EDUCATION, QUACQUARELLI SYMONDS RANKINGS OF PHILIPPINE HEIs, AND SCOPUS INDEXED RANKINGS

The quality of the higher education system always exerts a significant influence—if not the most significant influence—on the state of a country's science, technology, and innovation. There have been numerous attempts to assess the standing of higher education institutions (HEIs) globally. Some of the most widely recognized and well-regarded ranking systems include:

- Times Higher Education (THE) World University Rankings by Times Higher Education based in London
- Quacquarelli Symonds (QS) World University Ranking by the Quacquarelli Symonds based in London
- Academic Ranking of World Universities (ARWU) by the Shanghai Ranking Consultancy
- Performance Ranking of Scientific Papers for World Universities by the Higher Education Evaluation and Accreditation Council of Taiwan
- Ranking Web of World Universities by Cybernetics Lab, a unit of the Spanish National Research Council
- Center for Higher Education-Excellence Ranking by the Center for Higher Education Studies based in University College London
- University of Texas Dallas Top 100 Business School Research Rankings by the University of Texas Dallas School of Management

This Foresight will deal only with the ranking of selected Philippine HEIs in the THE World University Rankings and the QS World University Rankings, these two systems being the most frequently cited in academic and popular literature. The ARWU, though comparably as prestigious and recognized as the THE and QS systems, unfortunately has no Philippine HEIs listed in its website as of 2021 and is therefore not included in this Foresight.

With regard to scientific publications in refereed journals, the ranking of the Philippines based on Scopus Indexed Journals will be covered in this report.

Times Higher Education World University Ranking

Only two Philippine HEIs appear in the list of universities ranked by THE as of 2021: De La Salle University (DLSU), and University of the Philippines (UP). Table 1.4_1 shows the ranking of the two institutions from 2017-2021.

As indicated in Table 1.4_1, DLSU and UP generally rank in the lower half of surveyed universities. It should be noted that UP moved up from rank 801+ out of 981 universities in 2017 to rank 401-500 out of 1526 participating universities in 2021. Meanwhile DLSU moved slightly down the list, from rank 801-1000 out of 1259 universities in 2019 to 1001+ out of 1526 universities in 2021.

These rankings reflect both institutions' weaknesses in all five ranking criteria.

Table 1.4_1. THE World University Ranking of Selected Philipinne HEIs 2017-2021

Year	Top Score	Overall Ranking (values in parentheses are the overall scores)		Total number of universities covered
		DLSU	UP	
2017	95		801+ (8.3-18.5)	981 (79 countries)
2018	94.3		601-800 (21.5-30.6)	1103 (77 countries)
2019	96	801-1000 (19.0-25.9)	501-600 (33.5-37.0)	1258 (86 countries)
2020	95.4	1001+ (10.7-22.1)	401-500 (38.8-42.3)	1397 (92 countries)
2021	95.6	1001+ 10.3-25.0	401-500 (39.8-43.5)	1526 (93 countries)

Source: Times Higher Education (2020)
Notes: Philippines was represented in the Times Higher Education rankings from 2017 only.
The University of Oxford was the top scorer in all included years.

Table 1.4_2. THE World University Rankings Criteria

THE World University Rankings Criteria	
(1) Teaching (the learning environment)	**30%**
◦ Reputation survey	15%
◦ Staff-to-student ratio	4.5%
◦ Doctorate-to-bachelor's ratio	2.25%
◦ Doctorates-awarded-to-academic-staff ratio	6%
◦ Institutional income	2.25%
(2) Research (volume, income, and reputation)	**30%**
◦ Reputation survey *(university's reputation for research excellence among its peers)*	18%
◦ Research income *(scaled against academic staff numbers and adjusted for purchasing-power parity (PPP))*	6%
◦ Research productivity *(number of publications published in the academic journals indexed by Elsevier's Scopus database per scholar, scaled for institutional size and normalised for subject)*	6%
(3) Citations (research influence)	**30%**
◦ Citations to journal articles, article reviews, conference proceedings, books and book chapters published over five years are examined	
(4) International outlook (staff, students, research)	**7.5%**
◦ Proportion of international students *(ability of a university to attract undergraduates, postgraduates, and faculty from all over the planet)*	2.5%
◦ Proportion of international staff	2.5%
◦ International collaboration *(proportion of a university's total research journal publications that have at least one international co-author and reward higher volumes)*	2.5%
(5) Industry income (knowledge transfer)	**2.5%**
◦ The category suggests the extent to which businesses are willing to pay for research and a university's ability to attract funding in the commercial marketplace—useful indicators of institutional quality.	

Source: Times Higher Education (2020)

Notes: The Teaching and Research criteria are based on the responses to the annual Academic Reputation Survey.

Exclusions: Universities can be excluded from the World University Rankings if they do not teach undergraduates or if their research output amounted to fewer than 1,000 relevant publications between 2014 and 2018 (with a minimum of 150 a year). Universities can also be excluded if 80% or more of their research output is exclusively in one of our 11 subject areas.

Quacquarelli Symonds World University Ranking

The Quacquarelli Symonds (QS) World University Ranking has consistently ranked four Philippine HEIs since 2010:

- Ateneo de Manila University (ADMU)
- De La Salle University
- University of the Philippines
- Univeristy of Santo Tomas (UST)

Only UP is state supported; the rest are private sectarian universities (Table 1.4_3).

The latest version of the criteria used by the QS World University Ranking as of 2021 are indicated in Table 1.4_4.

The QS rankings of the four Philippine HEIs show that UP's ranking is in the range of 300-400, but is consistently improving in its percentile rank. Meanwhile, the number of universities in the list has been increasing from 500 in 2010 to 1,003 in 2021. ADMU ranked 307 out of 500 in 2010, and 601–

650 out of 1003 in 2021, placing in the same percentile rank albeit lower in absolute terms. DLSU and UST slipped significantly in their rankings between 2010 and 2021. A review of the latest ranking criteria can explain these shifts in the institutions' rankings.

Table 1.4_3. The Quacquarelli Symonds World University Ranking of Selected Philippine HEIs 2010-2021

<table>
<tr><th rowspan="2"></th><th colspan="12">Overall Ranking</th></tr>
<tr><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th></tr>
<tr><td>ADMU</td><td>307</td><td>360</td><td>451-500</td><td>451-500</td><td>501-550</td><td>461-470</td><td colspan="2">501-550</td><td>551-600</td><td>651-700</td><td colspan="2">601-650</td></tr>
<tr><td>DLSU</td><td>451-500</td><td>-</td><td>-</td><td>601+</td><td>601-650</td><td>651-700</td><td colspan="2">701+</td><td>701-750</td><td>701-750</td><td colspan="2">801-1000</td></tr>
<tr><td>UP</td><td>314</td><td>332</td><td>348</td><td>348</td><td>380</td><td>367</td><td>401-410</td><td>374</td><td>367</td><td>384</td><td>356</td><td>396</td></tr>
<tr><td>UST</td><td>-</td><td>-</td><td>-</td><td>601+</td><td colspan="4">701+</td><td colspan="4">801-1000</td></tr>
<tr><td>Tota Number of Universities Covered</td><td>500</td><td>499</td><td>500</td><td>726</td><td>833</td><td>863</td><td>891</td><td>916</td><td>959</td><td>1000</td><td>1002</td><td>1003</td></tr>
</table>

Source: QS World University Rankings (2020a)

Table 1.4_4. Quacquarelli Symonds World University Rankings Criteria

QS World University Rankings Criteria
(1) Academic Reputation........ 40% ◦ Based on QS Academic Survey, which collates expert opinions of over 100,000 individuals in the higher education space regarding teaching and research quality at the world's universities.
(2) Employer Reputation........ 10% ◦ Based on almost 50,000 responses to QS Employer Survey, and asks employers to identify those institutions from which they source the most competent, innovative, effective graduates.
(3) Faculty/Student Ratio........ 20% ◦ Proxy metric for teaching quality. It assesses the extent to which institutions are able to provide students with meanigful access to lecturers and tutors, and recognizes that a high number of faculty members per student will reduce the teaching burden on each individual academic.
(4) Citations per faculty........ 20% ◦ Institutional research quality is measured. To calculate it, we take the total number of citations received by all papers produced by an institution across a five year period by the number of faculty members at that institution.
(5) International Faculty Ratio........ 5% ◦ It demonstrates an ability to attract faculty and students from across the world, which in turn suggests that it possesses a strong international brand
(6) International Student Ratio........ 5% ◦ It demonstrates an ability to attract faculty and students from across the world, which in turn suggests that it possesses a strong international brand

Source: QS World University Rankings (2020b)

Scopus Indexed Rankings

As of April 2020, the Philippines is ranked 69 out of 240 countries in the World ranking of countries with the most number of Scopus indexed journals covering the period 1996–2019 (Scimago 2020, Scopus 2020). However, the Philippines is ranked 14th in the Asian regional ranking of Scopus indexed journals, with Singapore, Malaysia, Thailand, Indonesia and Vietnam ranked higher, as shown in Table 1.4_5 (Scimago 2020, Scopus 2020).

Table 1.4_5. Regional Ranking of Asian Countries Based on the Number of Publications in Scopus Indexed Journals, 1996-2019

Rank	Country	Documents	Citable documents	Citations	Self-citations	Citations per document	H index
1	China	716540	679955	2882171	1912222	4.02	1010
2	India	206648	182018	506414	202580	2.45	691
3	Japan	144883	125986	463150	130436	3.2	1118
4	South Korea	94142	87007	366234	85265	3.89	762
5	Indonesia	47432	46644	55764	28730	1.18	259
6	Taiwan	40516	36865	150418	28289	3.71	585
7	Malaysia	38228	36402	114103	32121	2.98	373
8	Hong Kong	26001	22985	161233	22610	6.2	639
9	Singapore	25537	21647	159129	23110	6.23	646
10	Pakistan	25343	23571	107369	33279	4.24	323
11	Thailand	20629	19322	57005	11702	2.76	369
12	Viet Nam	13068	11997	58466	18270	4.47	248
13	Bangladesh	8444	7865	26260	7275	3.11	225
14	Philippines	5888	5458	15786	3052	2.68	274
15	Kazakhstan	5214	4821	12175	3685	2.34	126
16	Sri Lanka	2937	2637	10372	1372	3.53	206
17	Macao	2378	2211	13037	1207	5.48	155
18	Nepal	2042	1805	6751	1132	3.31	159
19	Uzbekistan	1624	1473	3872	2184	2.38	105
20	Myanmar	787	728	2212	324	2.81	88
21	Mongolia	689	594	2203	349	3.2	110
22	Brunei Darussalam	609	555	2212	377	3.63	95
23	Cambodia	539	477	1972	277	3.66	119
24	Kyrgyzstan	454	391	2099	128	4.62	90
25	Laos	361	321	1299	167	3.6	95
26	Afghanistan	329	309	921	61	2.8	66
27	North Korea	245	213	695	133	2.84	37
28	Tajikistan	237	228	994	131	4.19	50
29	Bhutan	145	132	409	48	2.82	53
30	Maldives	47	42	193	27	4.11	35

Sources: Scimago (2020), Scopus (2020)

Important Developments Concerning the Rankings

These rankings are now being reviewed by the International Network of Research Management Societies to address concerns over the need for "fairer and more responsible university rankings." The indicators used are being challenged as not being representative of the universities' missions and may possibly "overlook societal impact or teaching quality." Twenty principles have been transformed into a tool to assess rankings, qualitatively and quantitatively (Gadd 2020).

With regard to the evaluation of scientific output, a group of editors and publishers have expressed the need to improve the evaluation process and the indicators used, including the Journal Impact Factor whose transparency is under question. These concerns are now articulated in the San Francisco Declaration on Research Assessment, signed as of 08 March 2021 by 19,254 individuals and organizations in 145 countries and the Leiden Manifesto with the following recommendations (Hicks et al. 2015; DORA 2020):

- Elimination of the use of journal-based metrics in "funding, appointment and promotion considerations."
- Assessment of research on the basis of its merits "rather than on the basis of the journal in which the research is published."
- Harness the advantage provided by online publication such as "relaxing unnecessary limits on the number of words, figures, and references in articles, and exploring new indicators of significance and impact."

It cannot be overemphasized that the Philippines' science community must actively participate in these discussions, to improve both the overall performance of university programs in global rankings and—more importantly—the quality and quantity of the programs' scientific outputs.

SECTION 1.5
THE PHILIPPINE INNOVATION SYSTEM

The linchpin of our national innovation system is the Intellectual Property Code (Republic Act 8293), signed into law on 06 June 1997. Republic Act (RA) 8293 protects the exclusive rights of scientists, inventors, artists, and other gifted citizens to their Intellectual Property (IP) and creations. The effective implementation of our national innovation strategy rests heavily on public-private partnership, while recognizing the role of government, especially the Department of Science and Technology (DOST), in strengthening linkages among key sectors. Public awareness of the benefits of innovation and entrepreneurial mindset are likewise important.

Even prior to the enactment of RA 8293, the value of inventions and their utilization was already recognized in RA 7459, the Inventors and Inventions Act of the Philippines, which was enacted into law on 28 April 1992. RA 7459 provides protection of inventors' exclusive rights to their inventions and grants them incentives in its development and commercialization.

The government continues to engender a policy environment conducive to innovation through such laws as the Philippine Technology Transfer Act (RA 10055), signed into law on 27 July 2009. RA 10055 lays down the policy that the state shall facilitate the transfer and promote the utilization of IP for the national benefit. It shall likewise establish the means to ensure greater public access to technologies and knowledge generated from government-funded research and development (R&D). This law explicitly gives the IPs and intellectual property rights (IPRs) generated by R&D institutions (RDIs) using funds provided by government funding agencies to the RDIs. It also allows various modalities for public-private collaboration to speed up the commercialization and utilization of the IP.

The fact that RA 10055 facilitated technology transfer from the RDIs to the private sector is evident in the increase in the number of technologies that had been commercialized since the passage of the law. In the University of the Philippines (UP) System, the Revised IPR Policy based on RA 10055 enabled the creation of offices and programs whose main purpose is to assist students and personnel in securing protection, licensing, and marketing of their creative outputs. The Office of the Vice-Chancellor for Research and Development of the University of the Philippines (UP) Diliman has listed several technologies for deployment for commercialization (as of 2014), one of which is "CoaTiN", an enhanced titanium nitride coating process that is environment friendly and low-cost, and which increases the lifetime of tools. Another award-winning technology being offered for commercialization is an effective oral vaccine for fish involving a novel process for microencapsulation of inactivated pathogens.

Recently, RA 11293, also known as the Philippine Innovation Act of 2018 was enacted with the following primary objectives:

- promoting a strategic planning and innovation culture
- improving innovation governance; coordinating and eliminating fragmentation of innovation policies and programs across levels of the government
- strengthening the position of micro, small, and medium enterprises (MSMEs) in the innovation system
- removing obstacles to innovations
- encouraging entrepreneurial culture; exploring, promoting, and protecting traditional knowledge, traditional cultural expressions, genetic resources
- strengthening interactions and partnerships among public and private sectors, academe, MSMEs, RDIs, and communities

The enactment of RA 11293 has paved the way for the establishment of the National Innovation Council, which adopts a “whole of government approach” that involves all government agencies to drive innovation across all areas.

In addition to RA 11293, the Congress also enacted RA 11337 or the Innovative Startup Act, whose development plan includes programs, incentives, and benefits for startups and startup enablers. The Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD) serves as one of the host agencies along with the Department of Trade and Industry (DTI) and the Department of Information and Communications Technology (DICT). This law complements RA 11293 through its emphasis on MSMEs and its role in fostering the country’s innovation economy.

The Harmonized National Research and Development Agenda

The DOST applies the enacted laws through the Harmonized National Research and Development Agenda (HNRDA) 2017-2022, which harnesses R&D for the country’s economic and social benefit. The HNRDA was conceptualized in consultation with government agencies, private institutions, academic institutions, and industry. The HNRDA is also aligned with the Filipino people’s aspirations in the 1987 Philippine Constitution, Philippine Development Plans, and AmBisyon Natin 2040.

Guided by the three pillars of AmBisyon Natin 2040—Malasakit (i.e., enhancing the Philippine social fabric), Pagbabago (reducing inequality), and Kaunlaran (increasing potential growth)—the HNRDA focuses on the following sectors (Figure 1.5_1):

(1) National Integrated Basic Research Agenda (NIBRA)
(2) Health
(3) Agriculture, Aquatic, and Natural Resources (AANR)
(4) Industry, Energy, and Emerging Technology
(5) Disaster Risk Reduction and Climate Change Adaptation (DRR CCA)

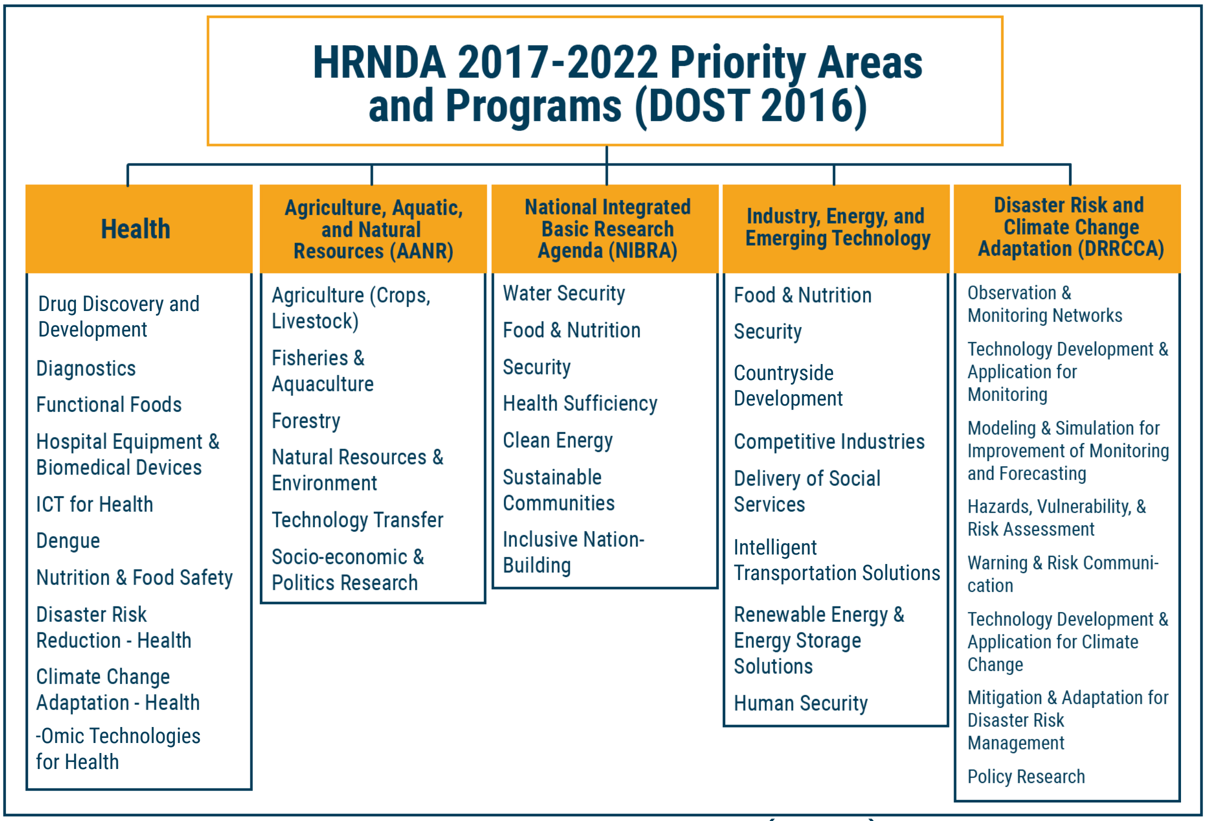


Figure 1.5_1. DOST's Harmonized National R&D Agenda (HRNDA)

The National Research Council of the Philippines (NRCP) is in charge of the NIBRA. For the years 2017-2019, the NRCP funded research on sustainable communities, inclusive nation-building, and health sufficiency. The NIBRA-related research studies have yielded scholarly publications, policy advisories, patent applications, and knowledge products. Meanwhile, the Philippine Council for Health Research and Development manages and coordinates health-related R&D studies. Their main priorities are diagnostics, drug discovery and development, and functional foods.

For the AANR, the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) focuses on advanced and emerging technologies, organic agriculture, food production and safety, and genetically modified organism development. Aside from these, PCAARRD seeks to modernize agriculture and fisheries through mechanization as mandated by RA 10601 or the Agricultural and Fisheries Modernization Law.

One of the most comprehensive programs in the HNRDA is on industry, energy, and emerging technologies which is being managed by Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD). Industry competitiveness is deemed as the most imperative priority area as it aids in countryside development. Moreover, DOST-PCIEERD has updated its R&D priority areas to include emerging industries such as space technology applications, artificial intelligence, human security and defense, and creative industries.

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) and Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) spearhead the program on DRR CCA. Guided by the United Nations Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction (2015–2030), PHIVOLCS and PAGASA give equal priority R&D to (1) monitoring and forecasting; (2) hazard and risk assessment; (3) warning; and (4) proper and timely response.

R&D Budget of Philippine Government Departments

Based on the General Appropriations Act, the allocation of public funds for R&D from 2017 to 2021 amounted to PHP92,426,672,708.00 for an average of PHP18,485,334,541.60 per year (Table 1.5_1). This resulted in an annual average ratio of 0.58% of the national budget. For the year 2020 alone, public R&D funding was a scant 0.105% of GDP, based on official data from the Bangko Sentral ng Pilipinas (BSP 2020).

For 2021, the DOST received the bulk of funds along with the Department of Agriculture (DA), with State Universities and Colleges (SUCs) also receiving substantial R&D funding. It is noted that the DICT did not receive any R&D budget for 2021, but was allocated substantial R&D funding from 2018 to 2020.

Table 1.5_1. R&D Budget of Government Departments Based on Unified Accounts Code Structure, 2017–2021

Name of Department	2017	2018	2019	2020	2021 GAA
DOST	6,310,249,000	8,185,719,000	6,154,983,000	7,086,628,000	10,173,078,000
DA	1,791,572,000	2,359,161,000	2,812,423,000	2,770,316,000	2,733,025,000
DENR	635,519,000	778,174,000	761,904,000	457,761,000	727,527,000
DOE	38,648,019	98,658,000	104,129,000	82,411,000	244,433,000
DND	130,155,000	132,567,000	137,298,000	189,125,000	249,375,000
DepEd	73,784,000	1,526,094,000	1,909,794,000	1,938,493,000	575,760,689
DILG	77,881,000	84,317,000	86,680,000	82,546,000	139,079,000
DOF	34,107,000	40,359,000	41,676,000	38,624,000	34,413,000
DOH	75,896,000	215,653,000	134,446,000	129,598,000	179,127,000
DOLE	31,696,000	33,887,000	18,782,000	18,853,000	45,859,000
DTI	40,071,000	29,144,000	38,694,000	66,868,000	63,749,000
ARMM	27,791,000	0	27,544,000	0	NAD
SUC's**	2,632,001,000	2,049,227,000	2,148,481,000	2,009,300,000	2,841,085,000
BSGC	693,219,000	482,347,000	992,736,000	1,226,990,000	809,129,000

Table 1.5_1. Continued

Name of Department	2017	2018	2019	2020	2021 GAA
Other Executive Offices*	835,485,000	921,579,000	767,909,000	755,487,000	804,594,000
DPWH	158,321,000	173,848,000	187,428,000	171,728,000	185,702,000
DICT	NA	2,645,012,000	3,289,139,000	1,600,479,000	0
DOTr	50,000,000	113,652,000	596,691,000	285,000,000	0
Total National R&D Budget	13,636,395,019	19,869,398,000	20,210,737,000	18,910,207,000	19,799,935,689
Total GAA (National Budget)	2,499,486,952,000	2,861,527,550,000	2,685,485,754,000	4,100,000,000,000	4,506,000,000,000
Ratio of National R&D Budget against National Budget (GAA)	0.55%	0.68%	0.75%	0.46%	0.44%

Source: DOST/M. Sahagun (personal communication, 21 July 2021)
For acronyms, please refer to List of Acronyms.

'Filipinnovation'

Aside from the HNRDA, the DOST has also adopted the "Filipinnovation" framework to improve science, technology, and innovation (STI) outputs. Filipinnovation is another whole-of-government approach to inclusive innovation that ensures coherent policies, aligned priorities, and collaboration among government agencies, academic institutions, industry, and civil society organizations. This framework also integrates the efforts of stakeholders such as the local government units, startups, MSMEs, R&D laboratories, S&T parks, incubators, fabrication laboratories, and investors (de la Peña 2020).

One of the first Filipinnovation collaborations is between the DOST and the DTI. The two agencies established several regional inclusive innovation centers (RIICs) with funding from the United States Agency for International Government. The RIICs work in tandem with Niche Centers in the Regions for Research and Development (NICER), with the former providing commercialization-related support to the universities that are part of the NICER Program. Other activities organized under the Filipinnovation framework are as follows (Guevara 2018):

(1) **Filipinovation Entrepreneurship Corps** – enables researchers to assess the commercial and societal value of their research
(2) **Funding Assistance for Spin-off and Translation of Research in Advancing Commercialization Program** – bridges the gap between R&D and commercialization particularly for DOST-PCIEERD funded technologies
(3) **Intellectual Property Management Program for Academic Institutions Commercializing Technologies** – aids Higher Education Institutions (HEIs) in setting up their technology transfer processes and facilitate commercialization of university-owned technologies
(4) **Venture Financing Program** — provides financial assistance for start-ups and technology-based expansion projects
(5) **Technicom** – fast tracks the market-readiness of local and supported communities' technologies

(6) **Small Enterprise Technology Upgrading Program (SETUP)** – helps MSMEs level up their industries
(7) **OneSTore** – allows customers to shop and retailers to reach customers and sell products by MSMEs
(8) **PCAARRD Innovation and Technology Center** – supports the implementation of Technology Transfer Act, Innovation Act, and IP Code

It is noted that the SETUP, a DOST program initiated over 15 years ago, has assisted MSMEs in acquiring technological innovations to improve their products, services, and operations in order to increase their productivity and competitiveness.

Science for Change Program

The DOST further strengthens its commitment to R&D with the Science for Change (S4C) program (DOST 2018) which focuses on Human Resource Development and R&D capacity-building and improvement. To sustain the efforts on capacity-building, the DOST has established the following (Figure 1.5_2):

(1) NICER Program (Figure 1.5_3)
(2) R&D Leadership (RDLead) Program
(3) Collaborative R&D to Leverage Philippine Economy (CRADLE) Program
(4) Business Innovation through S&T (BIST) for Industry Program

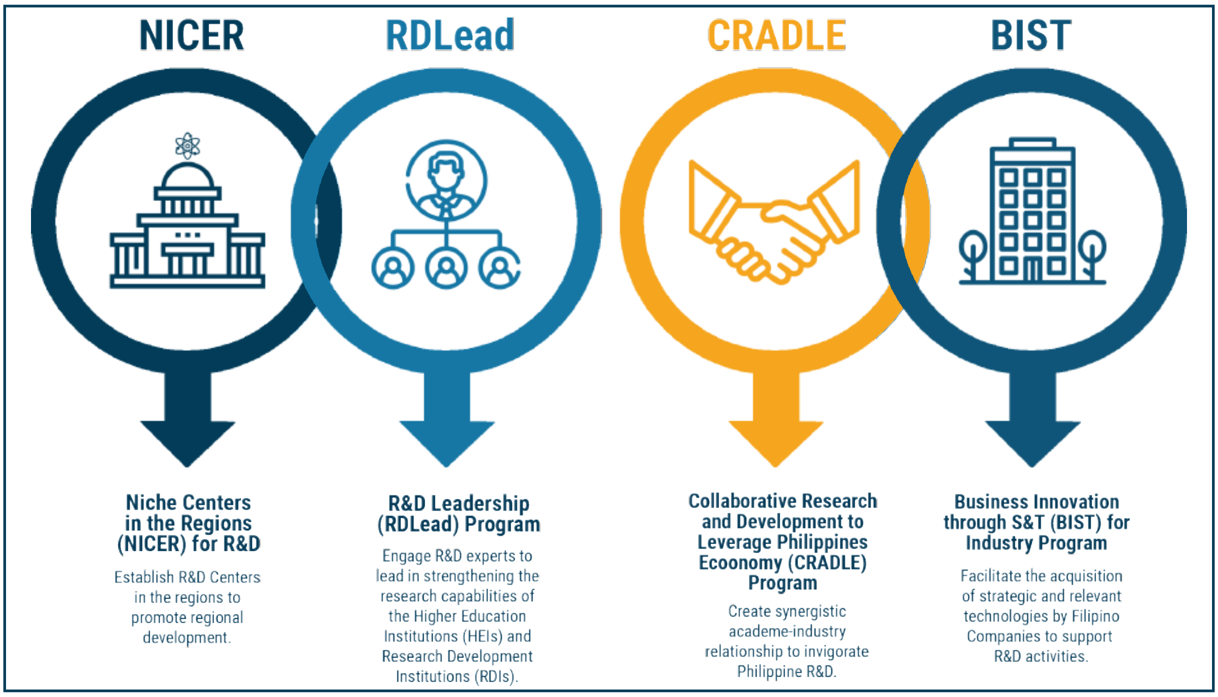


Figure 1.5_2. The Four Components of the DOST S4C Program
Source: DOST (2020) with modifications

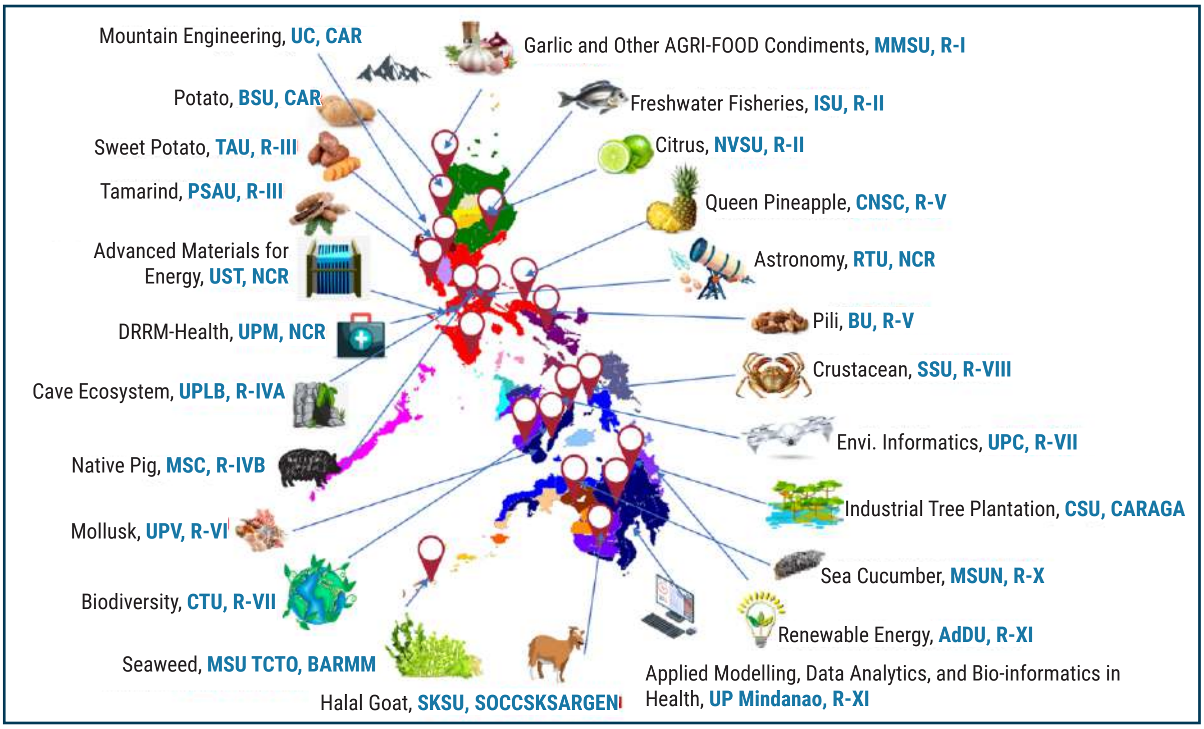


Figure 1.5_3. DOST-assisted Niche Centers in the Regions
Source: DOST (2020)
For acronyms, please refer to List of Acronyms.

The NICER Program seeks to improve the competitiveness of HEIs in the regions by establishing R&D centers and providing R&D institutional grants. Related to the NICER program is the RDLead Program that helps HEIs and RDIs upgrade their facilities and ensure the use of research results in policymaking and other development programs. Meanwhile, the DOST connects the HEIs and RDIs with the industry through the CRADLE Program. Industry identifies the problem while the HEIs and RDIs are given funding to undertake the R&D. The collaboration provides an opportunity for technology commercialization. The DOST also aids the industry by facilitating their acquisition of technologies as part of the BIST for Industry Program. Similar to the RDLead program, the BIST Program also provides R&D and technology acquisition funding for the industry.

Since its commencement, the S4C Program has doubled the number of HEIs that conduct R&D from 74 in 2014 to 149 in 2019. Funding had also increased for regions beyond Manila from 7% in 2014 to 20% in 2019. Moreover, the S4C Program, mainly through the CRADLE Program, has helped improve the country's Global Innovation ranking in terms of University-Industry research collaboration from 56th in 2018 to 27th in 2020. The country expects more research outputs, partnerships, and technology acquisition under the S4C Program in the coming years (de la Peña 2020).

R&D Infrastructure: The RDIs (excluding DOST RDIs)

In addition to RDIs and Niche Centers under the DOST, significant strides in the development of the country's R&D capacity were made through the establishment of specialized RDIs in HEIs. Most of these RDIs are recognized for their research productivity, to enable stronger collaboration between the research personnel of the RDI and the faculty of the HEI. The RDIs were created by Philippine laws, Presidential issuances, or the HEIs' Governing Boards orders.

University of the Philippines (UP) Los Baños hosts several of these RDIs. Notable among them is the Institute of Plant Breeding established on 05 June 1975 by PD 729. It is mandated to develop new and improved varieties of agricultural crops, except rice, through biotechnology and other breeding technologies. Its other important responsibility is to conserve plant genetic resources. Another RDI based in UP Los Baños is the National Institute of Molecular Biology and Biotechnology, established on 20 December 1979 by the UP Board of Regents. It specializes in agricultural, environmental, food and feeds, and health biotechnology to enhance agro-industrial productivity. Its products that have been commercialized include biofertilizers, biopesticides, vaccines, and diagnostic kits.

In UP Diliman, the oldest RDI is the Natural Sciences Research Institute, which was established in 1964 by RA 3887 and given the mandate to undertake research in biology, chemistry, environmental and atmospheric sciences, and mathematics, as well as to organize interdisciplinary research programs.

Other than DOST, DA and Department of Health (DOH) also have RDIs affiliated with them. The DA has the Philippine Carabao Center (PCC) and the Philippine Rice Research Institute (PHILRICE). Their main laboratories are located in the Science City of Munoz, Nueva Ecija, close to the Central Luzon State University. PHILRICE was established on 05 November 1985 through EO 1061 to develop high-yielding and cost-reducing rice technologies to help farmers produce sufficient rice for all Filipinos. The PCC was created by RA 7307 in 1992 with the responsibility of conserving, propagating, and promoting the carabao as a source of milk, as well as a draft animal.

The DOH Research Institute for Tropical Medicine was established in 1981 through EO 674 to conduct research in the diagnosis, control, and prevention of infectious and tropical diseases. Its research outputs have been utilized in the crafting of a national health policy and strategy.

Human Resources Development

Unleashing the benefits of science and technology for national development depends largely on the human resources that can be used to plan, implement, monitor, and evaluate the science and technology activities that will promote national well-being. The public and private sectors in the Philippines have been implementing programs to provide opportunities for those who would like to pursue careers in science, technology, engineering, and mathematics (STEM).

We shall discuss highlights on these initiatives in this section covering the period from the administration of President Corazon C. Aquino in 1986 to the conclusion of the term of President Benigno S. Aquino III in 2016.

It was during the term of President Corazon C. Aquino that the DOST was elevated to full cabinet status. This development triggered a series of initiatives to strengthen existing human development programs such as scholarships and to improve the teaching of STEM in basic education (K-12). Included in these initiatives is the upgrading of the skills of the workforce through technical and vocational education.

To better prepare students for careers in STEM, scholarships were offered for elementary and high school teachers who would like to specialize in STEM subjects. This was complemented by in-service training programs to update basic education STEM teachers. The Science Education Institute led in this effort by sustaining its support for the Regional Science Teaching Centers. In 1997, UP's science teaching program was further strengthened by the organization of the National Institute for Science and Mathematics Education Development. Gifted students interested in STEM careers were encouraged to study in the Philippine Science High School System. Science high schools and special science sections were established in the public schools and private schools. The construction and equipping of science laboratories in 110 public high schools were made possible from 1992–1998 through the Engineering and Science Education Project (ESEP). When the basic education program was reformed in 2013, STEM was offered as one of the four tracks at the senior high school level (Grades 11 and 12).

Building on the gains of past initiatives such as the undergraduate and graduate scholarships and training programs of the forerunners of the DOST—the National Science Development Board and the National Science and Technology Authority, the Philippine government availed of a loan of USD 85 million funded by the World Bank and the Overseas Economic Cooperation Fund of Japan to implement ESEP which was approved in the latter part of the administration of President Corazon C. Aquino and implemented during the term of President Fidel V. Ramos. Aside from the high school science laboratories that were constructed and equipped, ESEP supported the faculty development and upgraded research facilities in science and engineering programs in selected universities.

The "Science and Technology Scholarship Act of 1994" (RA 7687) expanded the scholarship slots for undergraduate degrees in STEM.

Programs were established to sustain the gains achieved in ESEP, to cope with the rapid developments in STEM, and enhance local capacity to undertake research and development. This involved expanding the pool of experts with master's and doctoral degrees in STEM to respond to the needs of academe and industry. Thus, the Engineering Research and Development for Technology and the National Science Consortium were put in place. This was expanded to the Accelerated Science and Technology Human Resource Development Program.

The former National Manpower and Youth Council was merged with the Bureau of Technical and Vocational Education into the Technical Education and Skills Development Authority by virtue of the "Technical Education and Skills Development Act of 1994" (RA 7796), which aims to develop the skills for various occupational areas, production, services, and livelihoods. As part of the STEM workforce, learners of trades and crafts supply competent apprentices by studying technologies and related sciences, and acquiring skills of practical value to the economy.

Retaining Highly-Trained Individuals

In addition to the earlier creation in 1976 of the Scientific Career System by Presidential Decree 997, the "Magna Carta for Scientists, Engineers, Researchers and other S&T Personnel in Government" (RA 8439) was enacted in 1997. The law provides for government S&T personnel a share of royalties, as well as hazard allowance, subsistence allowance, longevity pay, and funds for an annual medical examination, among others. Furthermore, in order to encourage and enable highly-trained Filipinos abroad to get involved in short-term and long-term STEM activities in the Philippines, the "Balik Scientist Act" (RA 11035) was enacted into law in 2018.

Conclusion

Current efforts to promote STI in the public and private sector are gradually being enhanced. Laws have been enacted to improve the environment for doing R&D. Unfortunately, there are still remnants of the inertia that have retarded the progress of STI in the country. We have been wanting in talent, and our knowledge infrastructure needs some overhauling. The challenge is to develop our capabilities in STI even while we are simultaneously developing our economy.

SECTION 1.6
GEOGRAPHIC FEATURES AND NATURAL RESOURCE ENDOWMENTS

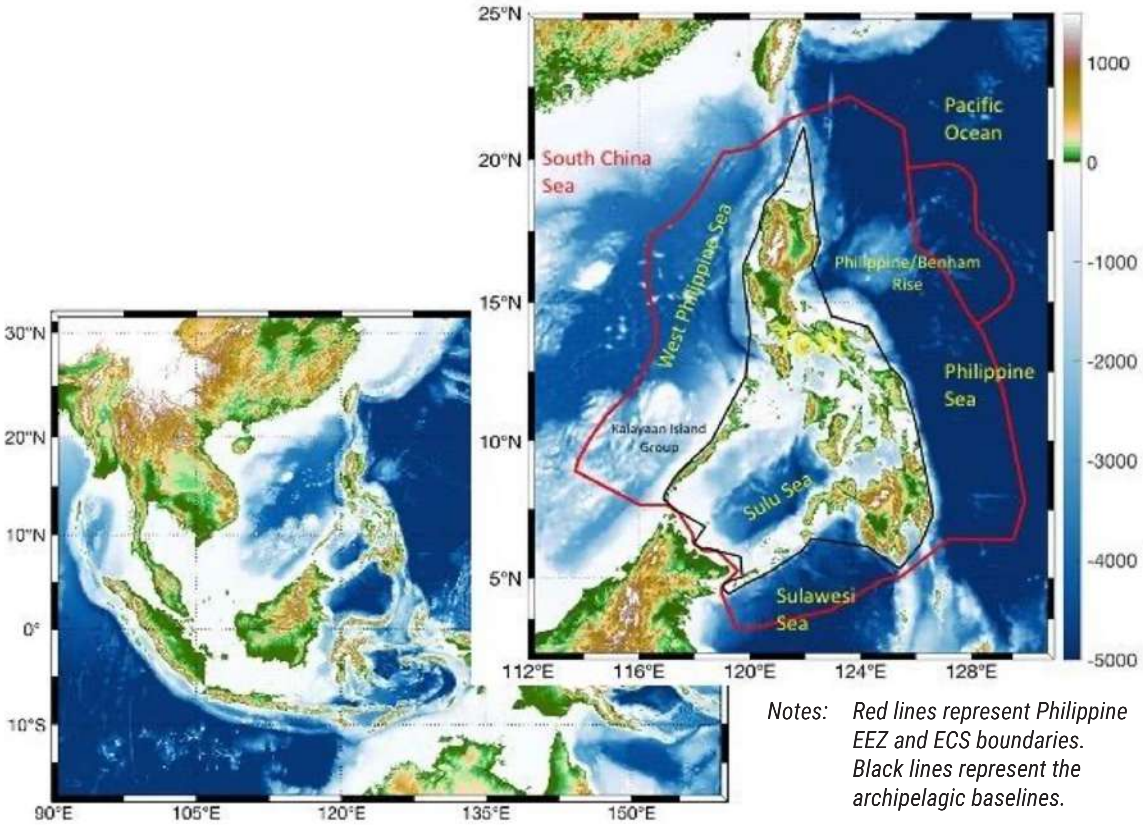
Geographic Features

The Philippines is a Southeast Asian archipelago with 7,641 islands, and ranked 5th among the world's largest island countries. It is located north of the equator between 3° to 22°N and 113° to 130°E. The Pacific Ocean bounds it on the east and many smaller water bodies, including Luzon Strait to the North, Sulawesi Sea to the south, and the South China Sea and the West Philippine Sea to the West (Figure 1.6_1). Administratively, it is divided into 17 regions and as of June 2020, there are 81 provinces; 146 cities; 1,488 municipalities; and 42,046 barangays (DILG 2020). In terms of land masses, there are three island groups—Luzon, Visayas, and Mindanao—with a total land area of 30 million ha classified into 15.8 million ha of forest land, and 14.2 million ha of certified alienable and disposable land (DENR-FMB 2019).

Sloping lands, comprised of mountains and hills, occupy 55% of the country's land area. The longest mountain range is the Sierra Madre in Luzon, which stretches some 540 km. There are about 24 active volcanoes. Meanwhile, there are at least 18 watersheds with an area of at least 100,000 ha that are classified as major river basins; 421 principal river basins; and 142 priority watersheds, of which 113 are proclaimed watershed forest reserves with an aggregate area of 2.46M ha (DENR-FMB 2019). There are also 216 lakes and 22 marshes, swamps, and reservoirs. Luzon's Laguna de Bay (900 km^2) is the largest lake in the country.

The country is generally tropical and maritime, and is characterized by relatively high temperatures, high humidity, and abundant rainfall. The mean annual temperature is 26.6°C. January is the coldest month, with a mean temperature of 25.5°C. May is the warmest month, with a mean temperature of 28.3°C. Mean annual rainfall varies between 965 and 4,064 millimeters.

The Philippine climate results from the interaction of the Asian Monsoon and many mountain ranges scattered across the country. The prevailing wind system is dominated by the Northeast Monsoon (locally called "amihan") from November to March, and the Southwest Monsoon ("habagat") from



Notes: Red lines represent Philippine EEZ and ECS boundaries. Black lines represent the archipelagic baselines.

Figure 1.6_1. Location of the Philippines Relative to Southeast Asia and Surrounding Bodies of Water.
Material prepared by: Acd. Villanoy
Note: EEZ - Exclusive Economic Zone, ECS - Extended Continental Shelf

June to October. The climate map in Figure 1.6_2 shows rainy conditions on the windward side of the mountain ranges. The seasonal reversal of the monsoons brings with it shifts in rainfall patterns. Fair weather dominates the monsoon transition months (April-May and October).

The country lies along the Pacific Typhoon Belt where an average of 20 tropical cyclones pass into area of responsibility annually, five of which are usually destructive. The tropical cyclones season lasts from June to November, but tropical cyclones do occur throughout the year (Figure 1.6_3).

The Philippines has a coastline measuring 36,389 km, ranked the 6th longest coastline worldwide. The entire sea area within all the maritime zones shown in Figure 1.6_1 is seven times greater than the land area. One can readily see several ocean bottom features. These include Benham (or Philippine) Rise, a 3,000 m deep underwater plateau found off the eastern coast of Luzon; the reef systems of the Kalayaan Islands, west of Palawan; and the broad shelf areas in northern Palawan and north of the Bicol Peninsula.

The topography of the sea bottom is as rugged, if not more so, than that of the land. The range of ocean depths (10,000 m) is about five times that of land (2,000 m). The shelf area (<100 m depth) accounts for about 8% of the total sea area. Half of the entire water sea is deeper than 4,000 m. The deepest points (>6,000 m) are within the Philippine Trench, located off Mindanao's eastern coast.

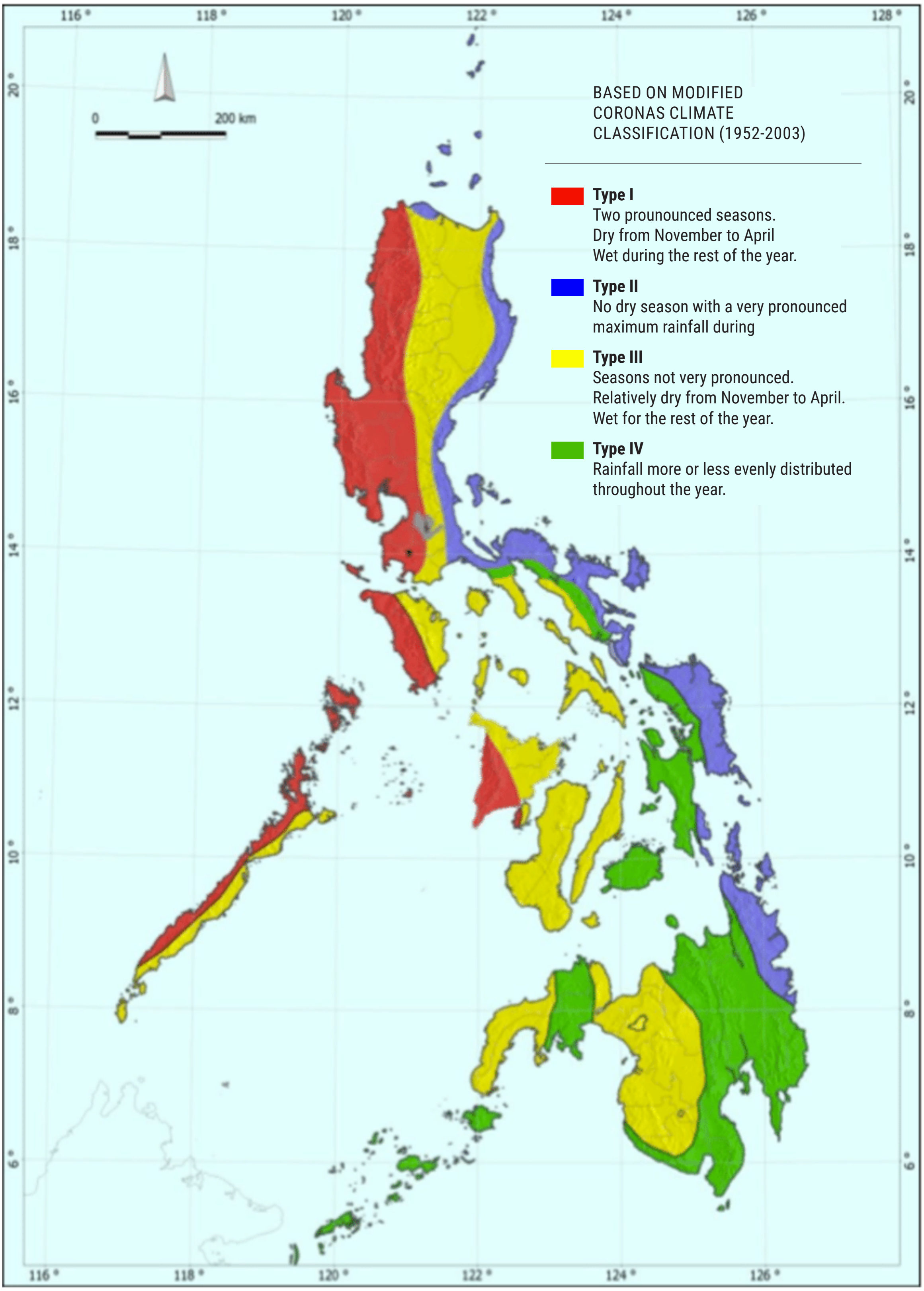
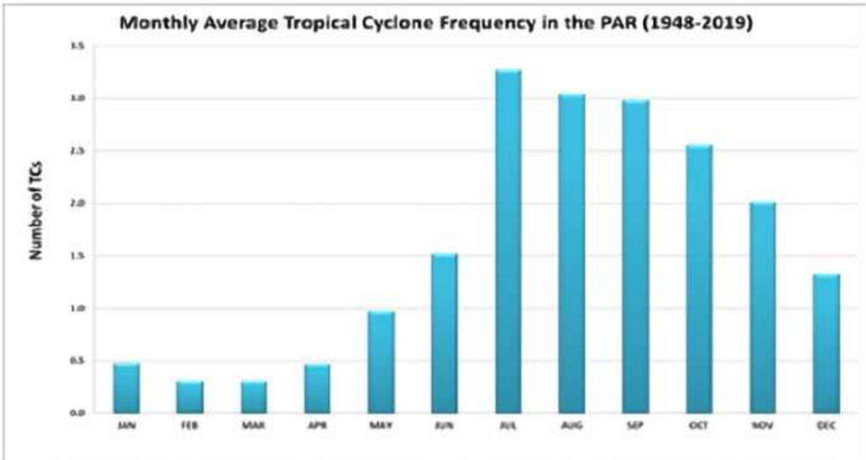


Figure 1.6_2. Climate in the Philippines
Source: DOST-PAGASA (2014)

FORECAST TROPICAL CYCLONE	
Month	Number of TC
DECEMBER 2020	1-2
JANUARY 2021	0-1
FEBRUARY 2021	0-1
MARCH 2021	0-1
APRIL 2021	0-1
MAY 2021	0-1



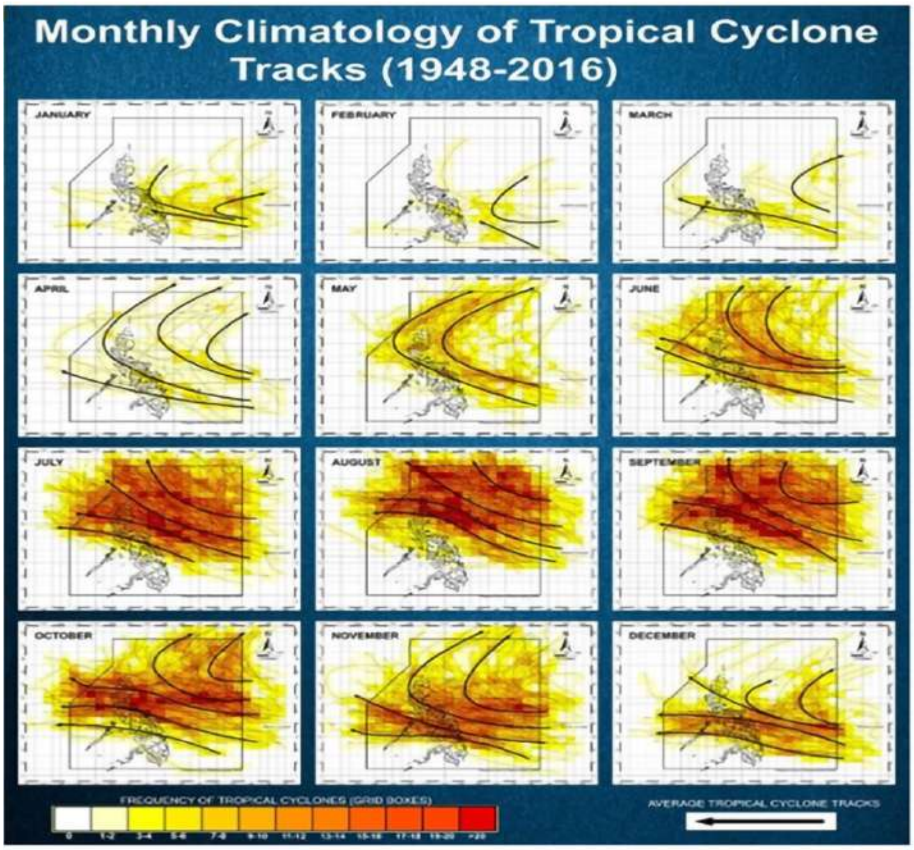


Figure 1.6_3. Historical and Projected Tropical Cyclone Activity in the Philippines as of December 2020

Source: DOST-PAGASA (2020)

TC - Tropical Cyclone

The complex seascape of the seafloor around the Philippines is the product of the area's very active geologic history and ongoing tectonic processes. Sandwiched between the Pacific Plate and the Eurasian plate, both sides of the archipelago are active collision plates with subduction within trenches and extensive faulting. Between the trench systems is an actively deforming region known as the Philippine Mobile Belt (PMB). The Philippine Fault System, a multi-branched left lateral strike-slip fault, cuts through the PMB from Pujada Bay to the Luzon Strait, with a length of about 1,400 km.

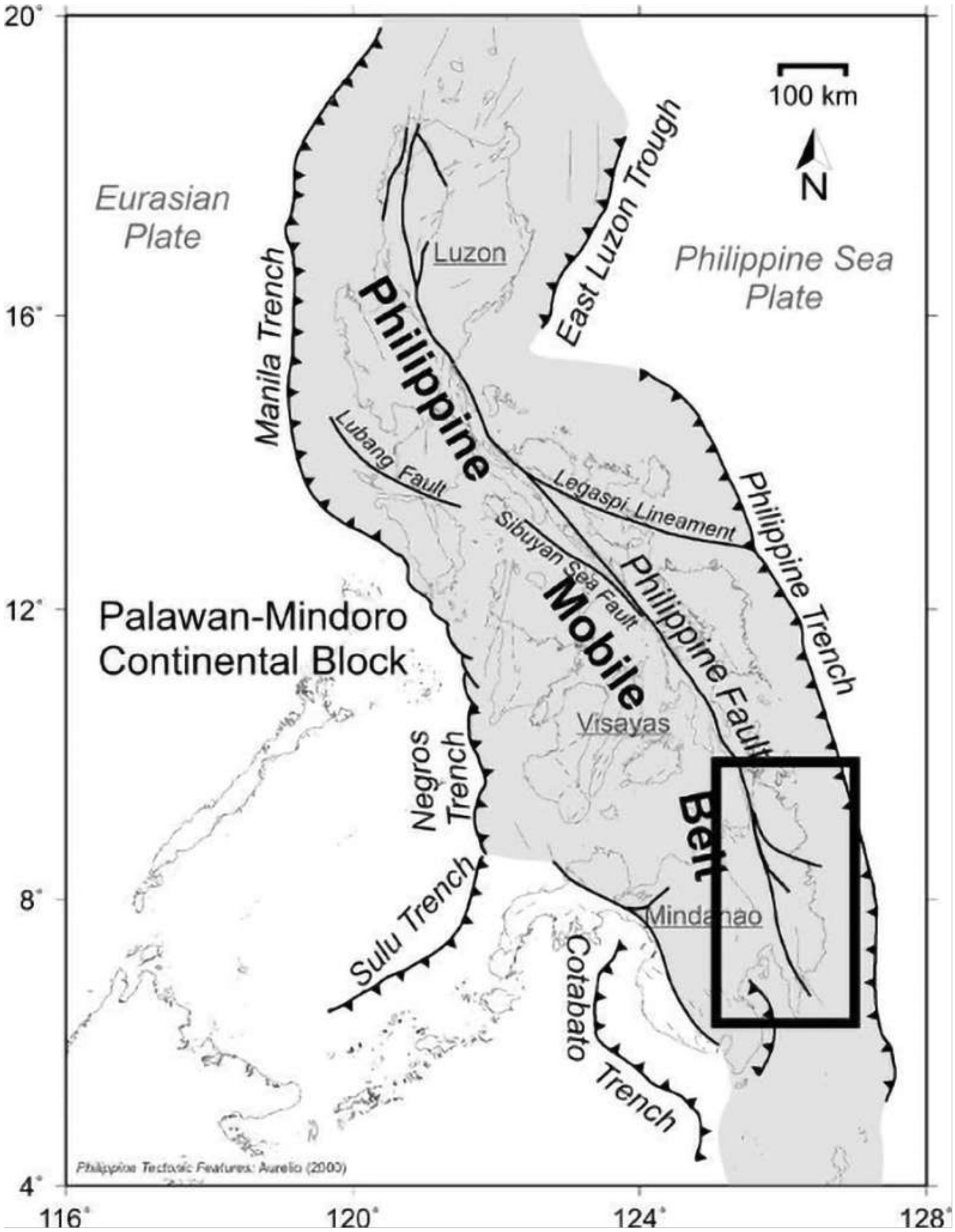
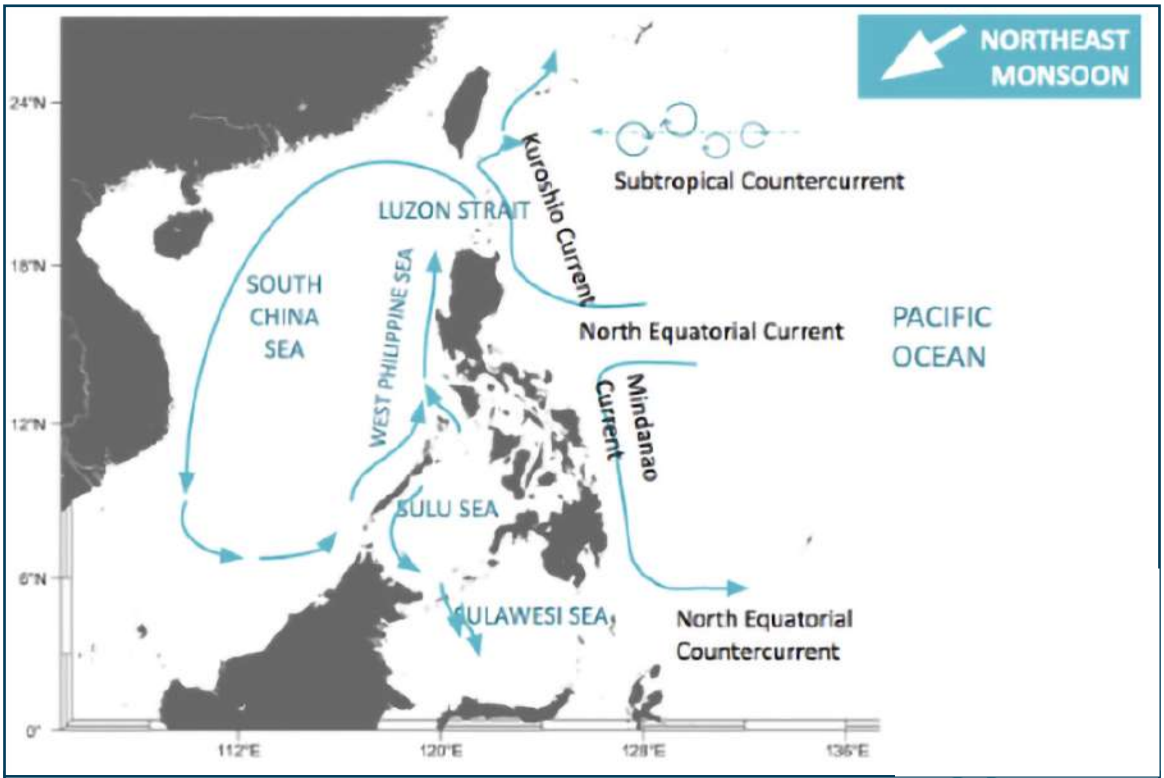


Figure 1.6_4. Map Showing Trenches Bounding the Philippine Mobile Belt
Source: Taguibao and Takahashi (2018)

The Philippines straddles the Pacific Ocean and the South China Sea. The large-scale currents of the Pacific influence the ocean currents on the Pacific side, and are usually persistent year-round (Figure 1.6_5). The stronger effects of the monsoon winds along the western coast drive ocean currents at seasonally-varying strengths.



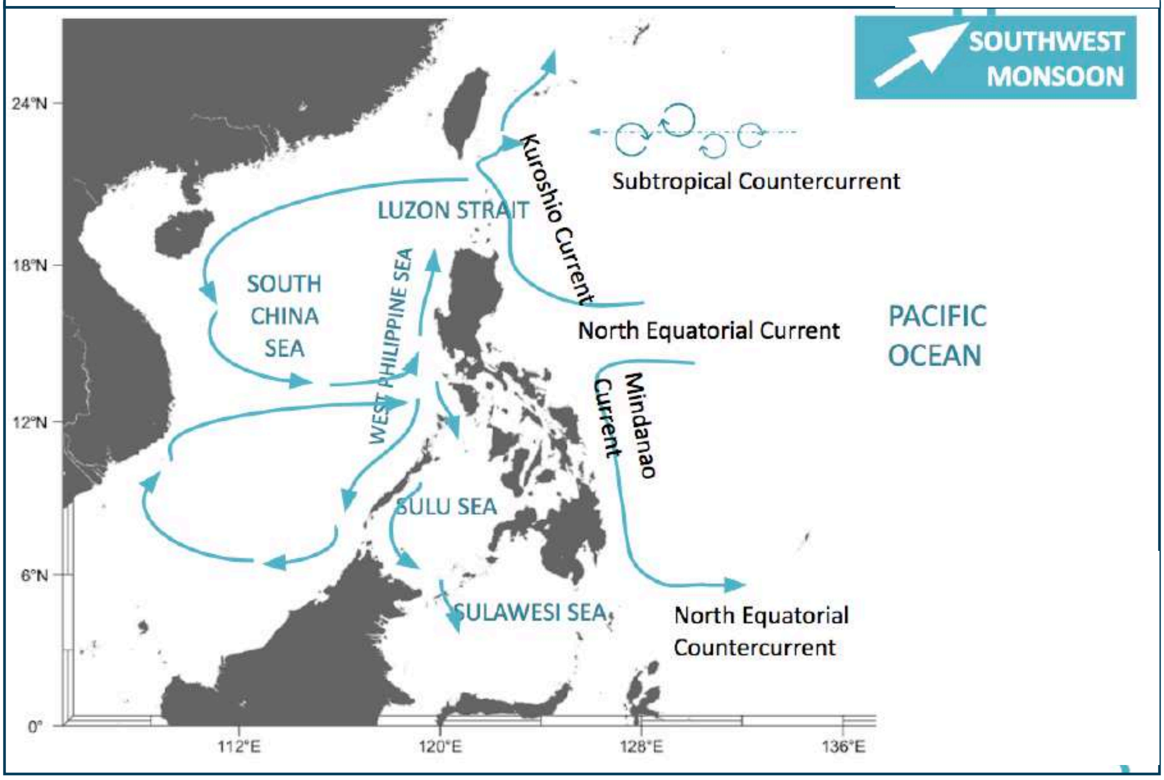


Figure 1.6_5. Schematic of Major Ocean Currents within Philippine Waters during the Northeast Monsoon (top), and Southwest Monsoon (bottom).
Source: Gordon et al. (2011)

The seas around the Philippines are very warm, except during the northeast monsoon (Figure 1.6_6). Some cooling is observed along straits and passages between islands during the peak monsoon months with strong vertical mixing driven by the wind's funneling effect. This mechanism also pumps nutrients from below the surface, enhancing phytoplankton production, and increasing biological productivity. These productive areas (and potentially-productive fishing grounds) appear in Figure 1.6_6 as areas with elevated chlorophyll concentration levels.

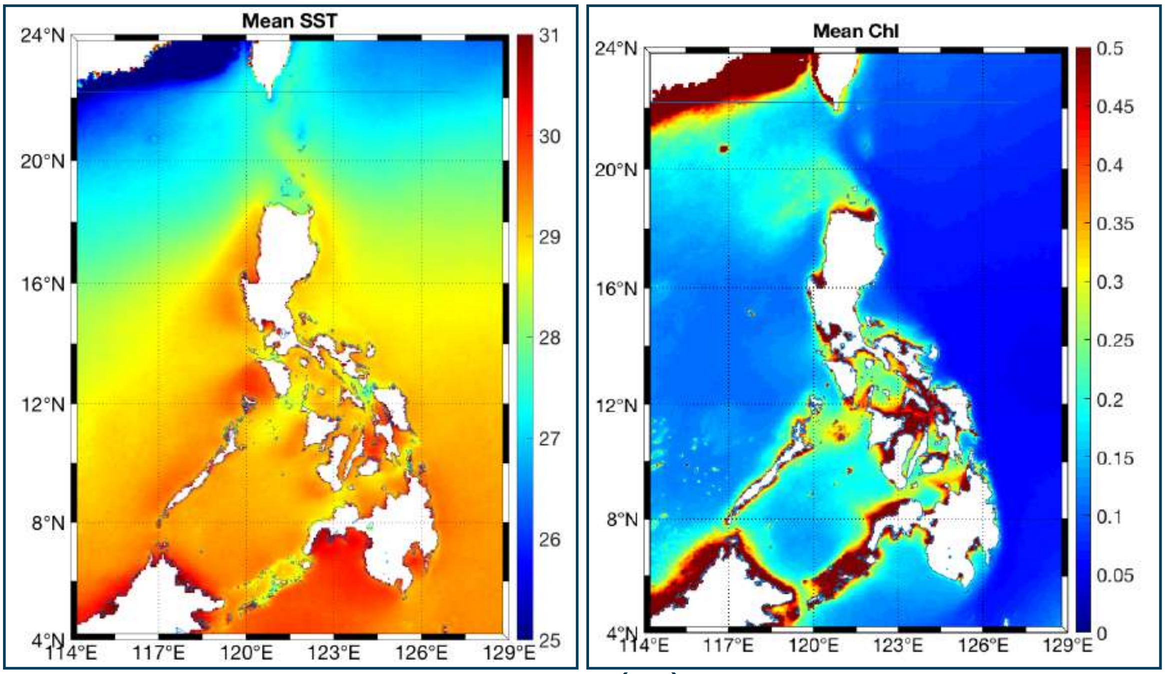


Figure 1.6_6. Mean Sea Surface Temperature (left) and Chlorophyll a Concentration (right) Averaged Over 2003-2019.

Source: MODIS
Material prepared by: Acd. Villanoy

Terrestrial Resources

Forests

Of the declared 15.8 million ha of the country's forest lands, only 7.01 million ha are covered with forests (DENR-FMB 2019). The remaining forest lands are classified as: closed forests (more than 40% of ground continuously covered by trees); open forests (10%-40% of the ground is discontinuously covered by trees); and mangrove forests (unique coastal forests). Closed forests cover 2.03 million ha of the remaining forest cover. Open forests share the greatest area, with as much as 4.68 million ha (see Figure 1.6_7). Mangroves only span 303,373 ha of the existing forest cover.

Minerals

The Philippines ranks fifth among the world's most mineralized countries, with nine million hectares of land that have high mineral content (DENR-MGB 2016). Major metallic minerals include gold, nickel, chromite, and copper. The major non-metallic minerals are limestone, marble, and coal.

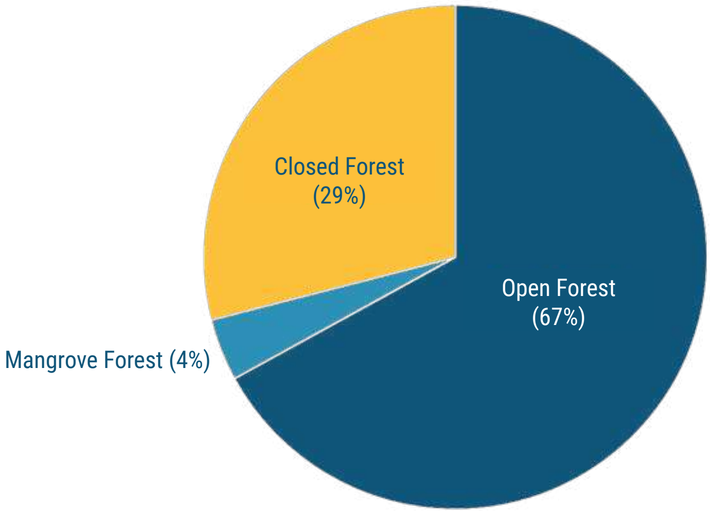


Figure 1.6_7. Forest Cover of the Philippines
Source: DENR-FMB (2019)

Table 1.6_1 shows the estimated mineral reserves for major metallic minerals and suggests the potential contribution of mining to the national economy, if sustainably managed. The country has concessions and infrastructure for:

- eight operating sites and two processing plants for gold
- 30 operating mines and two processing plants for nickel
- four operating sites for chromite
- three operating sites with one smelter plant for copper (PSA 2018e)

Table 1.6_1. Estimated Metallic Mineral Reserves from Year 2014 to 2018

Mineral	Reserve Volume				
	2014	2015	2016	2017	2018
Gold (Million kg)	4.859	4.840	4.831	4.887	4.894
Nickel (Billion mt)	1.985	1.991	1.962	1.957	2.051
Chromite (Million T)	40.288	40.237	40.247	44.904	44.859
Copper (Million mt)	1135.3	1135.3	1135.2	1135.1	1135.1

Source: PSA (2018e)

Water resources

The Department of Environment and Natural Resources (DENR) data shows the country's water supply is about 146 billion cu m, with 86% of piped-water supply systems supported by groundwater sources (DENR 2014).

The groundwater resources are estimated at 180 cu km/year, of which 80% (145 cu km/year) constitute the base flow of the river systems.

Groundwater reservoirs span 50,000 sq km which are freely recharged by rain, and seepage from rivers and lakes. It is estimated that rivers and lakes cover 61% of the country's total land area, and are potential water sources.

There 438 major dams, and 423 smaller dams (total of 861 impounding dam and reservoir sites) identified as sites with water surface and water storage potential. Recent estimates indicate that the total allocation rate for various water uses is 6.1 million liters per second.

Biodiversity

The Philippines is one of the world's 18 mega-biodiverse countries. It ranks 5th in the number of plant species, and maintains 5% of the world's flora. Species endemism is very high, with at least 25 genera of plants and 49% of terrestrial wildlife, while the country ranks fourth in bird endemism.

With habitat degradation, the country is considered as a biodiversity hotspot with at least 700 threatened species. Based on 2004 records, as many as 42 species of land mammals, 127 species of birds, 24 species of reptiles, and 14 species of amphibians were listed to be threatened. Fish biodiversity accounts to as much as 3,214 species, of which 76 are also threatened while 121 are endemic.

The estimated value for ecosystem services related to biodiversity conservation is about PhP 2.3 trillion. Ecosystem services related to crop production are worth about PhP 1.4 trillion. Carbon sequestration is valued at PhP 453 billion. Ecotourism is worth as much as PhP 157 billion (Table 1.6_2).

These values imply the need for more serious conservation for biodiversity resources.

Table 1.6_2. Ecosystem and Biodiversity Values (PhP Billion)

Ecosystem service	Estimated Value (PhP)
Ecotourism	157.0
Water provision	50.9
Carbon offset	453.0
Flood prevention	41.0
Soil erosion	10.0
Mangrove	7.4
Coral reef	62.1
Timber and fuelwood production	1.1
Fishery production	111.0
Crop production	1,416.0
Total	**2,309.5**

Source: DENR-BMB (2016)

Agricultural and Forestry Production

Agriculture. Agricultural lands are estimated at 14.48 million ha (PSA 2019). Major agricultural crops include: rice, corn, coconut, sugar cane, and banana. Major livestock include cattle, carabao, goat, hog, and poultry. The agriculture sector contributed 8.1% to the country's gross domestic product (GDP) in 2018. The country's GDP is estimated to have increased by 6.2% in 2020. The agriculture and fishing sectors recorded a 0.8% increase in production.

Forest Productions. In terms of timber products, roundwood production is estimated around 1.27M cu m in 2019 (DENR-FMB 2019). Of this, 5,021 cu m was exported. In terms of lumber, the country has produced about 246,000 cu m in the same year.

Of these, 89,000 cu m was exported. Further, 2019 records also showed that veneer and plywood products were as much as 285,000 cu m and 210, 000 cu m, respectively. Only the veneers were exported with a volume of 15,000 cu m.

Common non-timber forest products (NTFP) sold in the market are Almaciga resin (*Agathis philippinensis*), Anahaw leaves (*Saribus rotundifolius*), Bamboo poles (*Bambusa spp.*), Buri midribs (*Corypha elata*), Hingiw (*Ichnocarpus ovatofolius*), Nipa shingles (*Nypa fruticans*), Salago fiber (*Wikstroemia ovata*) and Rattan (*Calamus spp.*) Exported NTFPs in 2019 was worth as much as USD 940,000.

In terms of wood fuel, the rate of production (in '000 cu m) has increased over the years from 112,000 cu m in 2000, to more than double in 2005 (269,000 cu m), and continued increasing in the years 2010 (425,000 cu m) and 2015 (475,000 cu m). The country's annual wood fuel consumption rate is estimated at 57 milion tons.

Coastal and Marine Resources

Biodiversity

The country sits at the apex of the Coral Triangle and is reported to be the center of marine shorefish biodiversity. It is host to the highest number of marine fish per square area (Carpenter and Springer 2005, Sanciangco et al. 2013). Based on 2009 estimates, the number of fish species in the country is greater than 3,244, majority of which live in the marine areas (~80%), with 4% being endemic (Froese and Pauly 2009 in Alava et al. 2009).

The consensual Maximum Sustainable Yield (MSY) estimate for small pelagics is about 800,000 metric tons. The estimated MSY demersals is about 600 000 metric tons. Studies have indicated that most pelagic stocks, and demersal stocks are over-fished (Barut et al. 2003).

Commercially-important marine invertebrate resources include squids and cuttlefish, octopi, and crabs. Oceanic squid and deep-sea shrimp inhabit

Philippine territorial waters. Sharks, including chimaeras, true sharks, and flat sharks or batoids, make up 116 species, eight of which are new species descriptions (i.e., within the past five to 10 years), while 39 are considered potentially new species, possibly endemics, and require description (BFAR-NFRDI 2017).

There are 27 cetacean species, including a subspecies and one sirenian, reported and confirmed. They are all listed in Convention in International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices, and are fully-protected under RA 8550. Five turtle species are known to occur in the country. Their exploitation is banned under Ministry of Natural Resources Administrative Order No. 12, Series of 1979.

There are more than 400 species and 70 genera of hard coral, all of which are fully-protected under Philippine laws. Recent estimates indicate a continued decline in coral cover, where about a third of the reef coral has been lost over the last decade (Licuanan et al. 2019).

The country has about 18 seagrass species, which provide nurseries for certain aquatic species, export nutrients to adjacent habitats, and promote the settlement of waterborne silt, reducing the impact of siltation (Fortes 2013). About 824 species of marine macrobenthic algae–consisting of 214 species of green algae (*Chlorophyta*), 134 species of brown algae (*Phaeophyta*), and 472 red algae (*Rhodophyta*)—are found in the Philippines (Trono 1999).

Marine Protected Areas

A marine protected area (MPA) is a defined area of the sea established by law, administrative regulation, or other means, to conserve and protect an enclosed environment, in part or entirely, by establishing management guidelines. MPAs are categorized either as nationally-established and locally established. They can have several forms: marine sanctuary, marine reserve, fish sanctuary, marine park, protected seascape, etc. Cabral et al. (2014) pegged the total number of MPAs in the country at 1,800 (Figure 1.6_8).

Fisheries Production

In 2018, total fish production was reported as 4,356,874 metric tons, broken down into 946,437 metric tons from commercial fisheries; 1,106,071 metric tons from municipal fisheries; and 2,304,365 metric tons from aquaculture—all contributing about 1.2% (at current prices) and 1.3% (at constant prices) to the country's GDP (Table 1.6_3) (PSA 2018e).

The marine ecosystem alone (excluding the continental shelf) was conservatively valued to be about USD 966.6 billion/year, based on primary and available secondary data (Azanza et al. 2017).

Filipino fisherfolk, farmers, and children posted the highest poverty incidences in 2015 at 34.0%, 34.3%, and 31.4%, respectively (PSA 2019b). Fisherfolk belong to the poorest of the poor in Philippine society.

The University of the Philippines Marine Science Institute

Figure 1.6_8. Location of Marine Protected Areas in the Philippines
Source: Cabral et al. (2014)

Table 1.6_3. Volume of Fisheries Production by Sector, Philippines: 2016–2018 in Metric Tons

Sector	2016	2017	2018
All Sectors	4,355,792.42	4,312,089.51	4,356,874.77
Commercial Fisheries	1,016,948.05	948,281.45	946,437.62
Municipal Fisheries	1,137,931.03	1,126,017.30	1,106,071.84
Marine	976,941.19	962,146.84	941,870.86
Inland	160,989.84	163,870.46	164,200.98
Aquaculture	2,200,913.34	2,237,790.76	2,304,365.31
Brackishwater Fishpond	337,582.24	343,793.25	325,503.98
Brackishwater Fish cage	978.88	927.79	1,248.65
Brackishwater Fish pen	2,086.18	2,765.27	2,882.17
Freshwater Fishpond	145,655.32	156,465.15	161,519.66
Freshwater Fish cage	97,568.86	95,699.48	103,348.98
Freshwater Fish pen	56,610.84	62,805.43	57,644.07
Marine Fish cage	106,257.36	106,770.58	108.951.71
Marine Fish pen	11,307.24	11,019.69	9,867.59
Oyster	19,512.36	22,944.37	28,708.15
Mussel	18,774.55	19,208.62	26,302.77
Seaweed	1,404,519.23	1,415,320.79	1,478,300.85
Small Farm Reservoir	56.68	66.86	83.25
Rice Fish	3.59	3.49	3.47

Source: PSA (2019b)

Threats and Opportunities

The Philippines is richly endowed with terrestrial, coastal, and marine resources. While some of its precious resources have been badly exploited over time—forests, minerals, biodiversity, and fisheries—the country's natural resource base continues to support the needs of its increasing population, and its quest for development.

The next several decades will be crucial, as pressures from climate change, natural hazards, land and natural resource use, population, and economic growth intensify. This will heavily impact the country's natural resource endowments.

The act of balancing between development and protection of the environment and natural resources will become more challenging as more people require the use of our finite resources for livelihood and economic gains.

For terrestrial resources, a confluence of natural and anthropogenic pressures continue to threaten the sustainable production of various ecosystems' services that are vital to human well-being, and the pursuit of sustainable development.

While the Philippines has a significant fisheries sector and unique marine biodiversity, it is also a global hotspot for marine conservation, being right at the apex of the Coral Triangle of the Indo-Pacific Region–primarily due to several threats including overfishing, especially illegal, unregulated and unreported fishing (IUUF [date unknown]), habitat degradation, pollution, alien and invasive species, and climate change (Roberts et al. 2012).

In fact, the Philippines is one of the top 10 countries considered most vulnerable to the negative impacts of climate change (Santos et al. 2011).

Considering the current and anticipated threats to the country's natural resources, continuing assessment and monitoring of these resources will ensure their protection and sustainable management.

Science, technology, and innovation can, and should, play an important role in conservation and sustainable use of these resources.

SECTION 1.7
DEMOGRAPHICS AND DEVELOPMENT

The country's development, resilience, and sustainability depend greatly on the wise utilization of its natural endowments. A burgeoning population and rapid urbanization are just the tip of the iceberg when it comes to the Philippines' demographic and development trends. The country's annual population growth rate is currently 1.73%, while its annual urbanization rate is 1.32% (PSA 2015a), resulting in the overutilization and overexploitation of natural resources. This accelerated population growth translates into increased demand for food production and shelter.

The Philippines is blessed with abundant natural resources. Demand for access and use of natural resources, such as land and water resources across regions, also varies among different social classes based on their income and/or lifestyle. For example, water use in urban areas tends to be higher than in rural areas.

The resilience of households, communities, regions and countries is directly related to their adaptive capacity. Some indicators or measures of adaptive capacity include demographic variables such as age, level of education, income, human development index, etc. (IPCC 2014; Cruz et al. 2017). These indicators vary across regions, as well as within the regions themselves.

Demographics: Regional Distribution and Trends

The projected Philippine population by age group from 2020 to 2045 is shown in Table 1.7_1. The 0-24 age group, which is almost half (48.6%) of the population in 2020, will account for almost a third (36.5%) of the projected population by 2045.

Conversely, there is a steady increase in the percentage of population in the older age group from 2020 to 2045, which is more pronounced in the 45 to 80 age range. From a little more than a fifth (22.6%) in 2020, the 45 to 80 age group is projected to grow to a third (34.2%) of the projected population in 2045.

Table 1.7_1. Population Projection by Age Group, Philippines: 2020 - 2045

Age Group	2020	%	2025	%	2030	%	2035	%	2040	%	2045	%
All Age Groups	109,948	100.0	117,959	100.0	125,338	100.0	131,904	100.0	137,532	100.0	142,095	100.0
Under 5 Years	11,476	10.4	11,361	9.6	11,044	8.8	10,622	8.1	10,120	7.4	9,524	6.7
5 - 9 Years	11,234	10.2	11,386	9.7	11,274	9.0	10,958	8.3	10,536	7.7	10,032	7.1
10 - 14 Years	10,602	9.6	11,162	9.5	11,313	9.0	11,198	8.5	10,879	7.9	10,453	7.4
15 - 19 Years	10,209	9.3	10,524	8.9	11,081	8.8	11,227	8.5	11,108	8.1	10,783	7.6
20 - 24 Years	10,045	9.1	10,118	8.6	10,432	8.3	10,985	8.3	11,127	8.1	11,003	7.7
25 - 29 Years	9,540	8.7	9,944	8.4	10,017	8.0	10,329	7.8	10,878	7.9	11,016	7.8
30 - 34 Years	8,229	7.5	9,436	8.0	9,841	7.9	9,915	7.5	10,225	7.4	10,771	7.6
35 - 39 Years	7,239	6.6	8,127	6.9	9,334	7.4	9,742	7.4	9,819	7.1	10,130	7.1
40 - 44 Years	6,574	6.0	7,134	6.0	8,024	6.4	9,231	7.0	9,645	7.0	9,728	6.8
45 - 49 Years	5,787	5.3	6,450	5.5	7,016	5.6	7,909	6.0	9,116	6.6	9,537	6.7
50 - 54 Years	5,186	4.7	5,630	4.8	6,296	5.0	6,868	5.2	7,762	5.6	8,968	6.3
55 - 59 Years	4,319	3.9	4,971	4.2	5,421	4.3	6,087	4.6	6,665	4.8	7,557	5.3
60 - 64 Years	3,445	3.1	4,046	3.4	4,685	3.7	5,138	3.9	5,799	4.2	6,378	4.5
65 - 69 Years	2,472	2.2	3,110	2.6	3,684	2.9	4,301	3.3	4,750	3.5	5,397	3.8
70 - 74 Years	1,668	1.5	2,110	1.8	2,686	2.1	3,218	2.4	3,795	2.8	4,230	3.0
75 - 79 Years	967	0.9	1,313	1.1	1,689	1.3	2,183	1.7	2,653	1.9	3,170	2.2
80 Years and Above	958	0.9	1,138	1.0	1,501	1.2	1,993	1.5	2,657	1.9	3,421	2.4

Sources: PSA (2014a, 2018c)

Note: Median assumption in thousands ('000); Details may not add up to totals due to rounding.

The highest grade completed by household members 15 years old and above is depicted in Table 1.7_2. On the average, from 2013 to 2017, 44% had a high school education while a quarter (25%) reached college and graduate school level. Likewise, a quarter had elementary education, and a meager 2% had not completed any level of education at all.

It is also interesting to note the demographic differentiation of males and females in the workforce across regions in terms of educational attainment. Males outnumber females among those who attained only an elementary education, while the percentages of males and females across regions who completed secondary-level education are almost the same. However, there are more females than males in the labor workforce with baccalaureate degrees across all regions (PSA 2015a). This information is an important consideration in linking gender in development planning as educated and young people are more receptive to innovation.

Household income is another measure of resilience and adaptive capacity. Figure 1.7_1 shows the average annual income for a family of five members over a three-year interval, from 2006 to 2018. An increasing trend can be observed for all regions with the National Capital Region (NCR) consistently emerging with the highest family income followed by Region IV-A. Region III consistently came in third from 2006 to 2015, but lost its spot to the Cordillera Administrative Region (CAR) in 2018.

Table 1.7_2. Household Population for ages 15 Years Old and Above by Highest Grade Completed, Philippines: 2013–2017 (In Thousands)

Highest Grade Completed	2013		2014		2015		2016		2017	
Philippines	**64,173**	**%**	**64,033**	**%**	**64,936**	**%**	**68,311**	**%**	**69,891**	**%**
No Grade Completed	**1,158**	1.8	**1,126**	1.8	**1,108**	1.7	**1,127**	1.6	**1,235**	1.8
Elementary	16,340	25.5	15,629	24.4	15,616	24.0	16,673	24.4	16,729	23.9
Undergraduate	*7,974*		*7,436*		*7,583*		*8,494*		*8,779*	
Graduate	*8,367*		*8,192*		*8,033*		*8,180*		*7,950*	
SPED 1	NA		NA		NA		10	0.0	-	
SPED Undergraduate	*NA*		*NA*		*NA*		*8*		-	
SPED Graduate	*NA*		*NA*		*NA*		*2*		-	
High School 2	27,771	43.3	27,790	43.4	28,462	43.8	30,054	44.0	-	
Undergraduate	*10,267*		*9,875*		*10,206*		*11,518*		-	
Graduate	*17,504*		*17,915*		*18,256*		*18,535*		-	
Junior High School	NA		NA		NA		NA		30,214	43.2
Undergraduate	*NA*		*NA*		*NA*		*NA*		*10,852*	
Graduate	*NA*		*NA*		*NA*		*NA*		*19,362*	
Senior High School	NA		NA		NA		NA		1,013	1.4
Undergraduate	*NA*		*NA*		*NA*		*NA*		*953*	
Graduate	*NA*		*NA*		*NA*		*NA*		*60*	
Post Secondary	2,598	4.0	2,759	4.3	2,744	4.2	2,970	4.3	2,842	4.1
Undergraduate	*651*		*464*		*429*		*404*		*349*	
Graduate	*1,947*		*2,294*		*2,315*		*2,566*		*2,493*	
College	16,306	25.4	16,730	26.1	17,007	26.2	17,476	25.6	17,858	25.6
Undergraduate	*7,959*		*8,004*		*8,236*		*8,738*		*9,116*	
Graduate and Higher	*8,347*		*8,726*		*8,771*		*8,738*		*8,743*	

Source: PSA (2020c)

Notes:

1. Details may not add up to totals due to rounding.
2. Data averages of the four survey rounds (January, April, July and October).
3. Annualized data for 2014 refer to the average of estimates for April, July and October survey rounds. The estimates for these rounds exclude Leyte province.
4. Annualized data for 2015 refer to the average of the four survey rounds that exclude Leyte. The use of the four survey rounds that exclude Leyte was based on the results of the referendum conducted among members of the Interagency Committee on Labor and Productivity Statistics (IACLPS).
5. Starting April 2016 round, the Labor Force Survey (LFS) adopted the 2013 Master Sample Design as well as the population projections based on the 2010 Census of Population and Housing (2010 CPH) while previous survey rounds were derived using the 2000 CPH population projections.
6. Annualized data for 2016 was computed as the average of the four survey rounds using the January 2016 round that was based on the 2010 CPH population projections.

* Less than 500.
NA Not available.
1 Starting 2017, data for SPED is included under Elementary.
2 Starting 2017, High School data is broken down into Junior and Senior High School.

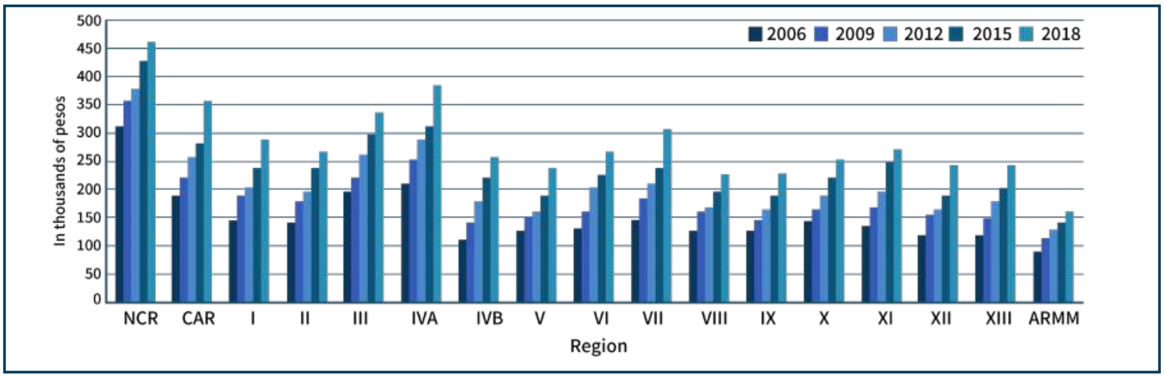


Figure 1.7_1. Average Annual Family Income by Region, 2016–2018
Sources: NSO (2006, 2009, 2012), PSA (2015a, 2018d)

On the other hand, the now-defunct Autonomous Region in Muslim Mindanao (ARMM), which has been replaced by the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) consistently showed the lowest reported annual family income from 2006–2018. The second lowest-ranked was Region IV-B (2006–2009), the Region V (2012–2015), and Region VIII (2018) while Region XII (2006, 2012, and 2015) and Region IX (2009 and 2018) came in third from the lowest during the indicated years.

Table 1.7_3 shows the per capita poverty threshold (i.e., the minimum income required for an individual to meet his/her basic food and non-food needs) and poverty incidence by region and province for the first semester of 2015 and 2018 (PSA 2018a, 2018b). Overall first quarter poverty incidence in the country decreased from 22.2% in 2015 to 16.1% in 2018. The NCR had the lowest first-quarter poverty incidence for both years (i.e., 4.6% in 2015 and 4.9% in 2018), while the ARMM had the highest poverty incidence: 56.2% in 2015 and 55.4% in 2018.

This trend is echoed by the annual per capita poverty threshold 1991 to 2015: all regions saw reduced poverty thresholds—by as much as 25.6 percentage points, in the case of Region II, from 37.3% to 11.7%—except for the ARMM, which saw an increase of 21.3 percentage points, from 26.9% to 48.2%. The NCR posted both the lowest thresholds and the smallest decrease over the period, from 5.3% in 1991 to 2.7% in 2015. As a whole, the poverty incidence in the Philippines decreased from 29.7% in 1991 to 16.5% in 2015 (PSA 2015c, 2018a).

Table 1.7_3. First Semester Per Capita Poverty Threshold and Poverty Incidence among Families with Measures of Precision, by Region and Province: 2015 and 2018

Region/Province	First Semester Per Capita Poverty Threshold (in PhP)		Poverty Incidence among Families (%)		Coefficient of Variation		Standard Error		90% Confidence Interval			
									2015*		2018	
	2015*	2018	2015*	2018	2015*	2018	2015*	2018	Lower Limit	Upper Limit	Lower Limit	Upper Limit
PHILIPPINES	**11,344**	**12,577**	**22.2**	**16.1**	**4.8**	**1.1**	**1.1**	**0.2**	**20.4**	**24.0**	**15.8**	**16.4**
National Capital Region (NCR)	**12,605**	**14,102**	**4.6**	**4.9**	**7.5**	**5.3**	**0.3**	**0.3**	**4.0**	**5.2**	**4.5**	**5.3**
1st District (City of Manila)	12,605	14,102	4.8	5.7	19.8	19.0	1.0	1.1	3.2	6.4	3.9	7.5
2nd District (City of Mandaluyong, City of Marikina, City of Pasig, Quezon City, City of San Juan)	12,605	14,102	3.9	3.5	14.9	12.6	0.6	0.4	3.0	4.9	2.7	4.2
3rd District (City of Caloocan, City of Malabon, City of Navotas, City of Valenzuela)	12,605	14,102	6.5	8.1	13.1	6.5	0.9	0.5	5.1	8.0	7.2	9.0
4th District (City of Las Piñas, City of Makati, City of Muntinlupa, City of Parañaque, Pasay City, Pateros, City of Taguig)	12,605	14,102	3.8	3.9	16.1	6.5	0.6	0.3	2.8	4.8	3.5	4.3
Cordillera Administrative Region (CAR) b/	**11,583**	**12,352**	**22.7**	**13.8**	**20.1**	**4.0**	**4.6**	**0.6**	**15.2**	**30.2**	**12.9**	**14.7**
Abra	11,361	12,406	36.8	29.5	9.1	6.1	3.4	1.8	31.2	42.3	26.5	32.5
Apayao	11,776	11,523	46.8	23.2	8.3	12.6	3.9	2.9	40.4	53.2	18.4	28.0
Benguet b/	10,778	11,820	5.2	6.1	20.1	10.4	1.0	0.6	3.5	6.9	5.1	7.2
Ifugao b/	12,553	12,944	43.9	15.5	21.7	11.4	9.5	1.8	28.2	59.6	12.6	18.5
Kalinga b/	10,679	11,864	26.6	12.3	22.1	10.1	5.9	1.2	16.9	36.2	10.2	14.3
Mt. Province	11,900	13,343	41.8	24.4	11.3	8.1	4.7	2.0	34.0	49.6	21.2	27.7
Region I (Ilocos Region)	**11,386**	**12,821**	**20.4**	**8.7**	**8.7**	**8.0**	**1.8**	**0.7**	**17.4**	**23.3**	**7.5**	**9.8**
Ilocos Norte b/	11,750	12,709	16.9	5.5	20.1	16.5	3.4	0.9	11.3	22.5	4.0	7.0
Ilocos Sur	11,865	11,907	15.0	8.8	19.5	11.2	2.9	1.0	10.2	19.8	7.2	10.4
La Union b/	10,923	10,866	19.0	3.7	21.6	18.7	4.1	0.7	12.2	25.8	2.6	4.8
Pangasinan	11,373	13,160	23.0	10.5	7.8	10.6	1.8	1.1	20.0	26.0	8.7	12.4
Region II (Cagayan Valley)	**11,328**	**12,142**	**17.3**	**15.3**	**5.4**	**5.5**	**0.9**	**0.8**	**15.7**	**18.8**	**13.9**	**16.7**
Batanes a/	15,314	19,249	10.0	13.3	0.0	11.9	0.0	1.6	0.0	0.0	10.7	15.9
Cagayan	10,841	12,199	18.4	15.1	11.3	8.9	2.1	1.3	15.0	21.8	12.9	17.3
Isabela	11,642	12,190	16.0	15.6	7.9	9.2	1.3	1.4	14.0	18.1	13.3	18.0
Nueva Vizcaya	11,525	11,934	17.6	16.9	17.5	10.0	3.1	1.7	12.5	22.7	14.1	19.7
Quirino	11,086	11,194	21.8	9.5	14.5	11.6	3.2	1.1	16.6	27.0	7.7	11.3

Table 1.7_3. Continued

Region/Province	First Semester Per Capita Poverty Threshold (in PhP)		Poverty Incidence among Families (%)		Coefficient of Variation		Standard Error		90% Confidence Interval			
									2015*		2018	
	2015*	2018	2015*	2018	2015*	2018	2015*	2018	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Region III (Central Luzon)	**11,224**	**12,885**	**12.2**	**7.8**	**7.8**	**4.7**	**0.9**	**0.4**	**10.6**	**13.7**	**7.2**	**8.4**
Aurora a/	10,289	12,050	24.6	16.7	0.0	9.9	0.0	1.6	24.6	24.6	13.9	19.4
Bataan b/	11,234	14,333	5.5	11.3	29.9	9.6	1.7	1.1	2.8	8.3	9.5	13.1
Bulacan	10,620	12,545	5.3	4.9	17.6	14.9	0.9	0.7	3.8	6.8	3.7	6.1
Nueva Ecija	11,346	12,287	23.4	10.3	9.7	10.1	2.3	1.0	19.7	27.1	8.6	12.1
Pampanga	10,668	12,795	4.8	3.5	16.8	19.7	0.8	0.7	3.5	6.1	2.4	4.6
Tarlac	11,024	11,917	19.8	10.3	12.1	9.1	2.4	0.9	15.9	23.8	8.8	11.9
Zambales	13,333	14,638	14.5	16.4	16.4	7.8	2.4	1.3	10.6	18.4	14.3	18.5
Region IV-A (CALABARZON)	**12,775**	**13,528**	**12.8**	**7.6**	**10.1**	**6.0**	**1.3**	**0.5**	**10.7**	**15.0**	**6.9**	**8.4**
Batangas	14,957	15,754	21.8	12.7	10.7	10.1	2.3	1.3	17.9	25.6	10.6	14.8
Cavite	13,669	14,440	9.7	6.0	14.1	13.2	1.4	0.8	7.4	11.9	4.7	7.3
Laguna b/	10,701	11,471	5.6	5.0	24.1	16.8	1.4	0.8	3.4	7.8	3.6	6.4
Quezon	10,530	11,357	23.5	12.2	16.5	12.9	3.9	1.6	17.1	29.9	9.6	14.8
Rizal	12,443	13,951	7.7	4.8	17.1	15.4	1.3	0.7	5.5	9.9	3.6	6.1
MIMAROPA Region	**10,189**	**11,420**	**22.9**	**15.0**	**7.7**	**4.7**	**1.8**	**0.7**	**20.0**	**25.8**	**13.9**	**16.2**
Marinduque	9,963	11,672	23.9	14.2	12.4	9.2	3.0	1.3	19.0	28.8	12.1	16.4
Occidental Mindoro	10,176	10,577	32.4	22.0	16.1	9.6	5.2	2.1	23.8	40.9	18.5	25.5
Oriental Mindoro	10,369	12,032	21.7	12.8	14.3	10.6	3.1	1.4	16.6	26.8	10.6	15.0
Palawan	9,833	11,339	17.9	11.2	17.9	10.1	3.2	1.1	12.6	23.2	9.4	13.1
Romblon b/	10,777	11,862	26.8	24.3	22.1	7.4	5.9	1.8	17.1	36.6	21.3	27.2
Region V (Bicol Region)	**11,431**	**11,946**	**33.7**	**21.4**	**6.8**	**3.6**	**2.3**	**0.8**	**29.9**	**37.5**	**20.1**	**22.6**
Albay	11,378	12,208	24.8	15.9	12.0	8.0	3.0	1.3	19.9	29.7	13.8	18.0
Camarines Norte	12,015	12,117	40.1	24.6	16.6	7.0	6.6	1.7	29.1	51.0	21.8	27.5
Camarines Sur	11,420	11,575	31.3	19.2	8.6	8.7	2.7	1.7	26.8	35.7	16.5	22.0
Catanduanes	11,297	12,144	37.3	19.4	8.5	8.3	3.2	1.6	32.1	42.5	16.7	22.0
Masbate	10,398	11,285	33.0	29.4	16.9	7.0	5.6	2.1	23.8	42.2	26.0	32.8
Sorsogon	11,907	13,114	46.7	24.5	13.5	6.7	6.3	1.6	36.3	57.1	21.8	27.2
Region VI (Western Visayas)	**0,932**	**11,937**	**25.0**	**15.9**	**7.5**	**4.9**	**1.9**	**0.8**	**21.9**	**28.1**	**14.6**	**17.2**
Aklan	11,056	12,069	25.4	14.6	16.7	10.2	4.2	1.5	18.4	32.4	12.2	17.0
Antique	10,226	11,680	27.0	18.3	19.3	9.6	5.2	1.7	18.4	35.6	15.4	21.1
Capiz b/	10,326	10,984	18.3	5.9	27.4	13.1	5.0	0.8	10.0	26.6	4.6	7.2
Guimaras a/ b/	11,501	12,602	19.4	12.4	37.6	11.5	7.3	1.4	7.4	31.4	10.1	14.8
Iloilo	11,471	12,590	22.0	15.8	14.1	7.5	3.1	1.2	16.9	27.2	13.8	17.7
Negros Occidental	10,763	11,604	29.5	18.5	8.2	8.5	2.4	1.6	25.5	33.5	15.9	21.1

Table 1.7_3. Continued

Region/Province	First Semester Per Capita Poverty Threshold (in PhP)		Poverty Incidence among Families (%)		Coefficient of Variation		Standard Error		90% Confidence Interval			
									2015*		2018	
	2015*	2018	2015*	2018	2015*	2018	2015*	2018	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Region VII (Central Visayas)	**11,210**	**12,696**	**28.5**	**19.0**	**4.8**	**4.2**	**1.4**	**0.8**	**26.2**	**30.7**	**17.7**	**20.3**
Bohol	11,200	12,613	25.9	21.1	12.1	8.3	3.1	1.8	20.7	31.1	18.2	24.0
Cebu	11,451	12,859	24.1	16.5	6.6	5.9	1.6	1.0	21.5	26.7	14.9	18.1
Negros Oriental	10,835	12,396	40.6	26.1	9.2	8.4	3.8	2.2	34.4	46.8	22.5	29.7
Siquijor a/	10,658	12,454	49.7	10.0	0.0	15.8	0.0	1.6	49.7	49.7	7.4	12.6
Region VIII (Eastern Visayas)	**11,227**	**12,201**	**39.9**	**30.4**	**6.4**	**3.4**	**2.6**	**1.0**	**35.7**	**44.1**	**28.7**	**32.1**
Biliran	10,831	12,037	16.1	18.0	7.7	7.9	1.2	1.4	14.0	18.1	15.7	20.4
Eastern Samar	12,971	14,112	42.9	43.0	16.0	5.0	6.9	2.2	31.5	54.2	39.4	46.5
Leyte	10,819	11,732	38.4	29.4	8.1	6.5	3.1	1.9	33.3	43.5	26.2	32.6
Northern Samar	11,502	12,648	53.8	30.0	8.9	6.6	4.8	2.0	45.9	61.6	26.7	33.3
Southern Leyte	11,863	12,672	31.7	22.8	18.3	7.2	5.8	1.6	22.1	41.2	20.1	25.5
Western Samar	10,634	11,238	43.9	32.2	13.8	6.6	6.0	2.1	34.0	53.9	28.7	35.6
Region IX (Zamboanga Peninsula)	**11,038**	**12,388**	**33.9**	**32.4**	**10.8**	**3.4**	**3.7**	**1.1**	**27.8**	**39.9**	**30.5**	**34.2**
Zamboanga del Norte	12,028	13,609	51.7	41.2	7.2	5.9	3.7	2.4	45.5	57.9	37.2	45.2
Zamboanga del Sur	10,120	11,829	23.2	25.2	17.2	5.8	4.0	1.5	16.6	29.7	22.8	27.6
Zamboanga Sibugay	10,602	11,436	39.4	36.0	12.6	7.1	5.0	2.5	31.2	47.6	31.8	40.2
Isabela City a/ b/	10,518	12,607	20.7	52.6	30.2	6.2	6.2	3.3	10.4	30.9	47.3	58.0
Region X (Northern Mindanao)	**11,426**	**12,232**	**35.9**	**25.4**	**6.8**	**3.1**	**2.4**	**0.8**	**31.9**	**39.9**	**24.1**	**26.7**
Bukidnon	11,886	12,678	54.1	32.1	5.6	6.3	3.0	2.0	49.1	59.1	28.7	35.4
Camiguin a/	11,883	2,671	40.0	23.2	6.0	8.8	2.4	2.0	36.0	44.0	19.8	26.5
Lanao del Norte	11,346	12,114	42.2	23.6	11.7	6.0	4.9	1.4	34.0	50.3	21.3	26.0
Misamis Occidental	10,697	11,994	36.9	32.4	11.9	6.3	4.4	2.0	29.7	44.2	29.1	35.8
Misamis Oriental	11,007	1,838	18.4	18.5	15.8	5.1	2.9	0.9	13.6	23.2	16.9	20.1
Region XI (Davao Region)	**11,585**	**12,709**	**21.4**	**17.7**	**7.1**	**4.0**	**1.5**	**0.7**	**18.9**	**23.9**	**16.6**	**18.9**
Davao del Norte	12,016	12,720	27.2	14.5	17.6	10.3	4.8	1.5	19.3	35.1	12.1	17.0
Davao del Sur	11,603	12,968	12.1	10.7	13.7	10.2	1.7	1.1	9.4	14.9	8.9	12.6
Davao Oriental	11,404	12,643	28.0	32.6	16.0	6.6	4.5	2.1	20.6	35.3	29.1	36.2
Compostela Valley	11,386	12,502	29.2	25.8	8.7	6.7	2.6	1.7	25.0	33.4	23.0	28.7
Davao Occidental	11,332	12,510	51.2	36.7	9.0	6.7	4.6	2.5	43.6	58.7	32.6	40.8
Region XII (SOCCSKSARGEN)	**10,576**	**12,067**	**37.4**	**27.2**	**6.5**	**3.7**	**2.4**	**1.0**	**33.4**	**41.4**	**25.5**	**28.9**
North Cotabato	10,452	11,773	42.3	25.6	8.1	8.3	3.4	2.1	36.7	48.0	22.1	29.1
Saranggani	10,051	11,043	53.0	40.5	12.0	7.3	6.4	3.0	42.5	63.5	35.6	45.4
South Cotabato	10,661	12,504	23.6	18.9	12.1	8.1	2.9	1.5	18.8	28.3	16.4	21.4
Sultan Kudarat	10,543	11,555	49.0	32.4	14.7	7.2	7.2	2.3	37.1	60.9	28.6	36.3
Cotabato City b/	12,730	14,804	39.9	42.3	27.3	5.8	10.9	2.5	21.9	57.9	38.3	46.4

Table 1.7_3. Continued

Region/Province	First Semester Per Capita Poverty Threshold (in PhP)		Poverty Incidence among Families (%)		Coefficient of Variation		Standard Error		90% Confidence Interval			
									2015*		2018	
	2015*	2018	2015*	2018	2015*	2018	2015*	2018	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Region XIII (Caraga)	**11,299**	**12,314**	**35.2**	**28.3**	**5.7**	**3.2**	**2.0**	**0.9**	**31.9**	**38.5**	**26.8**	**29.8**
Agusan del Norte	10,119	11,430	28.4	23.5	12.2	5.7	3.5	1.3	22.7	34.1	21.3	25.7
Agusan del Sur	11,490	12,095	45.0	32.4	7.6	6.8	3.4	2.2	39.4	50.6	28.8	36.0
Surigao Del Norte	12,253	13,742	32.8	32.2	13.1	6.8	4.3	2.2	25.7	39.9	28.7	35.8
Surigao Del Sur	11,361	11,945	32.8	23.9	11.1	7.4	3.6	1.8	26.8	38.8	21.0	26.8
Dinagat Islands	12,132	13,177	45.4	36.7	18.8	6.8	8.5	2.5	31.3	59.4	32.6	40.8
Autonomous Region in Muslim Mindanao (ARMM)	**11,183**	**13,578**	**56.2**	**55.4**	**5.8**	**2.4**	**3.3**	**1.3**	**50.8**	**61.5**	**53.2**	**57.6**
Basilan	9,856	12,671	28.8	65.3	12.8	3.4	3.7	2.2	22.7	34.9	61.6	68.9
Lanao del Sur	12,021	14,769	73.8	68.0	4.9	3.2	3.6	2.2	67.8	79.8	64.5	71.5
Maguindanao	9,979	12,653	47.4	47.9	8.2	6.6	3.9	3.1	41.0	53.8	42.8	53.1
Sulu	11,494	13,830	71.8	65.8	8.5	3.4	6.1	2.3	61.7	81.8	62.1	69.6
Tawi-tawi b/	8,895	9,817	10.9	17.2	32.8	9.1	3.6	1.6	5.0	16.8	14.7	19.8

Source: PSA (2020c)

Notes:

a/ Caution in utilizing the estimate for these provinces must be observed due to its very small sample size.

b/ Coefficient of variation of first semester 2015 provincial poverty incidence among families is greater than 20%.

* Food Thresholds are estimated using actual prices collected by PSA for the estimation of the Consumer Price Index (CPI). In consonance with the updating of the market basket for the collection of prices for CPI, First Semester 2015 Poverty Statistics were revised accordingly.

Urbanization

Meanwhile, population growth is exerting pressure on available land and water resources. Rapid urbanization often leads to land use and cover changes due to unregulated land conversion and unsustainable production systems. Figure 1.7_2 shows that the urban communities increased from 45.3% in 2010 (PSA 2010) to 51.2% in 2015 (PSA 2015a) especially in Region IV-A (CALABARZON) including the provinces of Mindoro Oriental, Mindoro Occidental, and Palawan.

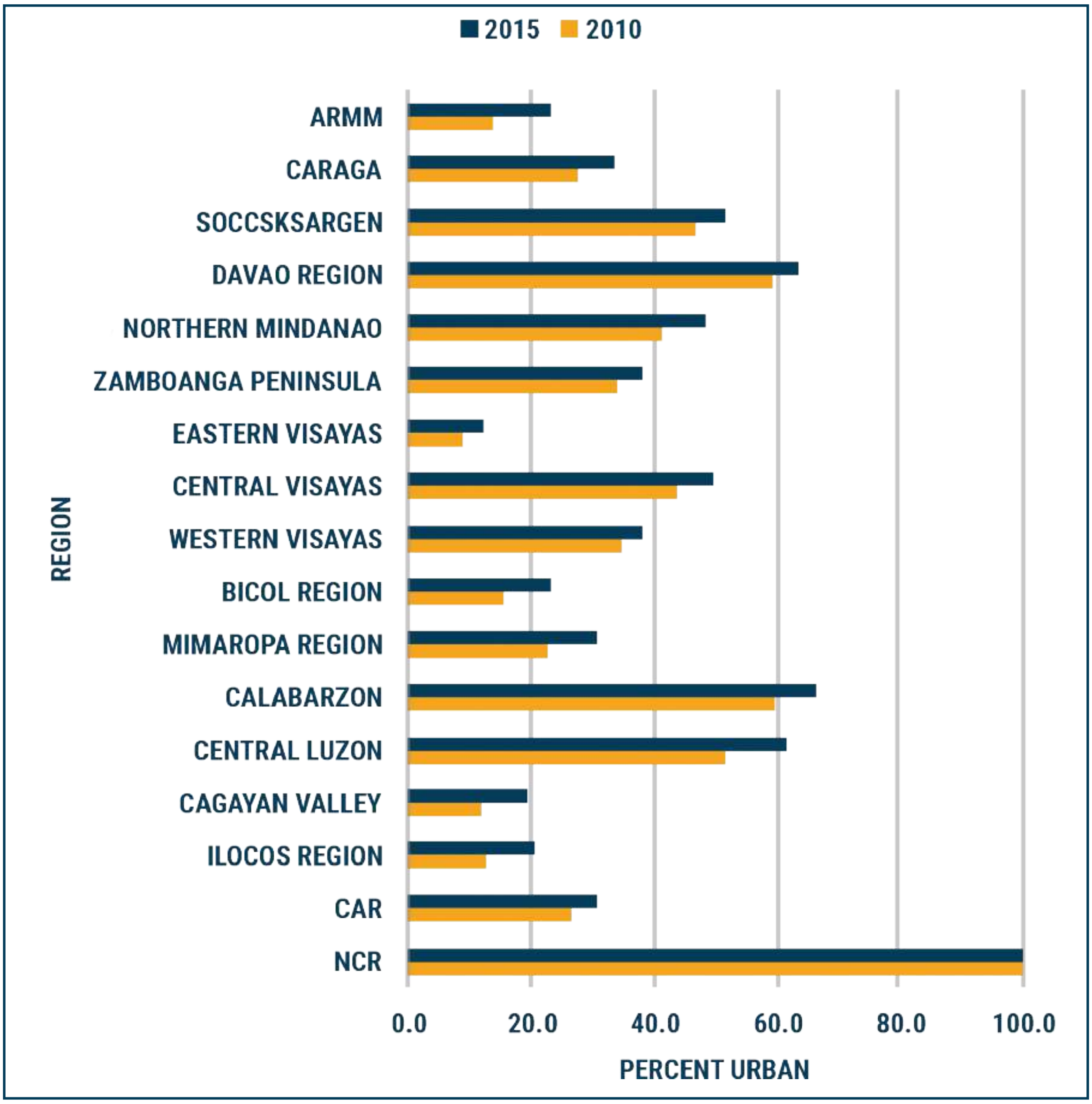


Figure 1.7_2. Level of Urbanization by Region in 2010 and 2015.
Sources: PSA (2010, 2015a)

Implication of Demographics to Science, Technology, and Innovation Development

Almost half of the population currently belongs to the age group 0-24 and will be a potential source of the talent pool for science, technology, and innovation (STI). Access to formal education and skills training will be a crucial factor in our ability to maintain a critical mass of highly trained and skilled workers, and those who will engage in STI activities especially in research and development and science and technology services. However, by 2045, only a third of the population will be in this age bracket. Measures should be instituted to manage this decrease.

The differences in the demographics of the regions will require targeted STI interventions calibrated to the characteristics and needs of the regions, especially for livelihood, education, and health services.

Abrigo et al. (2020) attribute the progress made by the Philippines in improving average incomes and consumption in the past 25 years to the country's favorable demography. This demographic dividend should be provided with opportunities to contribute to sustainable growth.

DIGITAL ARTWORK

Amorsolo 2050

Primary conceptual idea by Jerome Suplemento II
Art by Julius Sempio

Fernando Amorsolo is famous for preserving in the warm amber light of his paintings the romantic essence of Philippine rural life in the 20th century—depictions, if not of how things are, then at least of how they might or could be. Here, we bring one of the great master' s most iconic landscapes into the future, with a vision of how the latest advancements in science and technology, when properly designed and implemented, can harmoniously coexist or be integrated into traditional ways of life. Just as Amorsolo captured the ephemeral essence of Philippine rural life, so too do we hope for S&T to flourish and become so commonplace as to be all but invisible in even the most far-flung farms of the 21st century.

Disclaimer: The views and opinions expressed in the artworks do not necessarily reflect the official policy or position of the NAST PHL.

SECTION 2

Megatrends: From COVID-19 to Space and Beyond

SECTION 2.1
MEGATRENDS IN POPULATION, MIGRATION, POVERTY, AND INEQUALITY

The demographic profile of the world has changed tremendously over the past three decades, as total fertility has declined and as life expectancy has risen. Migration, both internal and international, has also expanded due to labor shortages, whether in highly-developed urban areas or in advanced countries, and, more broadly, as a response to existing inequalities in incomes and economic opportunities across places.

Population growth and migration movement are two factors that have impacted global and regional poverty and inequality changes in the last three decades. Poverty has declined over this period, but it has declined unevenly across different regions of the world. Inequality has dropped across some countries but has risen within many others. Moving forward and over the long term, climate change, technological development, and the current COVID-19 crisis are expected to impact the movement of people, the distribution of populations, and the evolution of poverty and economic inequality. The country's capacity to harness science, technology, and innovation (STI) is key to turning these trends into opportunities for rapid, sustainable, and inclusive socioeconomic development.

Population

World population growth has been positive, but declining, over the past few decades. World population grew at 2% per year from 1960 to 1970 (1960s), at 1.9% in the 1970s, 1.8% in the 1980s, 1.5% in the 1990s, and 1.2% in the 2000s and 2010s (UN DESA 2019).

Declining fertility rates (from 5.0 in 1960-65 to 2.5 in 2015-20) and longer life expectancy means population growth has varied widely across age groups. Annual average population growth for those 65 years and above actually rose from 2.6% in the 1960s to 3.2% in the 2010s. In contrast, annual average population growth for those in the 15-64 age group (working age) declined from 1.8% to 1.1% in the same period, while growth of those 14 years and below dropped even steeper from 2.1% to 0.6%.

Population growth varied widely across different regions of the world. In Sub-Saharan Africa, the population grew at 2.7% per year from 1990 to 2020, but in the Philippines and the rest of East Asia and the Pacific, the population only grew at 0.9% per year. East Asia and the Pacific are rapidly aging, as the population of those 65 years and older grew at 3.2% annually in the past three decades, while the population of those in the 15-64 age group grew 1.1%, and those 14 years and below actually declined by -0.6% per year. As a consequence, in the same period, the share of those aged 14 years and below in the total population declined from 29.7% to 19.6%, while the share of those 65 years and older almost doubled from 5.7% to 11.2%. Within East Asia and the Pacific, declining population growth and increased ageing were particularly sharp in the more developed countries of the region, such as Japan, Korea, and Taiwan.

For many developing Asian countries, the rapid decline in population growth over the past three decades has meant a decline in the dependency ratio (ratio of 15-64 population to sum of 0-14 population and 65+ population), which has contributed positively to their rapid economic development. This growth in the economy attributed to changes in the age structure of the population has been termed the "demographic dividend." Some studies have estimated that about one-third of the economic growth achieved by the tiger economies of East Asia from 1965 to 1995 were from the demographic dividend (Bloom and Canning 2001; Bloom and Williamson 1997; Radelet et al. 1997, as cited in Mapa 2015).

The countries in the best positions to avail of the demographic dividend are those where the working-age population have quality education and good health, and where there are sufficient quality jobs to absorb them (UNFPA 2016). The Philippines has yet to benefit fully from the demographic dividend because of the slow decline in its fertility rate (Mapa and Balisacan 2004). For more advanced countries, however, the extended decline in population growth has led to the ageing of the population and, in some cases, labor shortages that have posed or are posing a threat to further economic growth, absent adjustments such as large-scale automation, economic restructuring, or migrant worker inflow (Ducanes and Abella 2008).

In the next three decades, these demographic shifts will continue to have an impact on economic growth and well-being, especially as developing countries, including the Philippines, transition to higher income status. The expected shift of manufacturing to greater automation, and the pressure that change will exert on lower-skill work, poses a particular challenge to countries that have yet to benefit from the demographic dividend.

The world population was estimated at 7.9 billion in 2020, and it is projected to grow to 9.7 billion by 2050, with half of the population growth coming from Sub-Saharan Africa. In Southeast Asia, specifically, the total population is expected to grow from 669 million in 2020, to 794 million in 2050, with the population expected to rise in all countries except for Thailand.

Climate change is projected to have a huge impact on the distribution of the population within and, even, across countries. A World Bank (WB) report focusing on Sub-Saharan Africa, South Asia, and Latin America, projects more than 143 million migrating internally by 2050 due to climate change (Rigaud et al. 2018).

A study by the European Commission, meanwhile, projects climate change can drive anywhere from 25 million to one billion people into internal or external migration by 2050 (Artuso and Guijt 2020). This includes people moving away from lower water availability and crop productivity, and coastal areas with rising sea levels and storm surges. This projection may be especially important for the Philippines, which is visited by an average of 20 typhoons per year and has experienced five of the strongest tropical cyclones in history—four of which were experienced just in the last 10 years (Masters 2020).

Migration

Globally, the number of external or international migrants was estimated at 272 million in 2019, equivalent to about 3.5% of the global population; this is up from 2.8% in 2000 and 2.3% in 1980 (UN 2020). Of the total international migrants in 2019, some 84 million are in Asia, 82 million in Europe, 59 million in North America, and 27 million in Africa. About 60% of these migrants moved for work reasons. The still-large income differential between most origin and destination countries, the better standards of living in many destination countries, robust migrant networks, labor shortages in some developed but ageing countries, and the declining cost of travel have contributed to the high—and still burgeoning—level of global migration.

About 40% of all international immigrants in 2019 came from Asia, and about half of these Asian migrants moved to other Asian countries (IOM 2019). In absolute numbers, the Asian countries with the largest number of migrants abroad are India and China, but a large number of Asian immigrants also came from Bangladesh, the Syrian Arab Republic, Pakistan, the Philippines, Afghanistan, and Indonesia.

Pre-COVID-19, international migration was expected to continue to grow across Asia and the rest of the world given demographic pressures, more open borders and greater ease of travel, and the existing disparities in income and economic opportunities across countries. However, the pandemic has resulted in travel restrictions and other constraints that halted migration in many existing corridors. In fact, the crisis could potentially result in the displacement and return of millions of migrant workers to their countries of origin (ILO 2020).

For the Philippines, which has depended on foreign remittances since the 1980s, the latest reports as of November 2020 show that over 250,000 overseas Filipino workers were repatriated since the onset of the pandemic (DFA 2020), affecting not just household incomes, but also economic mobility.

Indeed, for as long as the COVID-19 threat is present, international migration is unlikely to pick up. Further, the longer-term effects of the pandemic on international migration remains uncertain.

Poverty

Global and regional poverty have rapidly declined over the past three decades. Global extreme poverty (based on Purchasing Power Parity $1.90-a-day poverty line) declined to 10% in 2015—the latest year for which data is available—from 36% in 1990 (World Bank 2020b). The reduction in poverty cuts across all regions of the world, but very unevenly.

Extreme poverty in East Asia and the Pacific experienced a steep drop from 61% in 1990 to only 2% in 2015, and further, to just one percent in 2018. In the Sub-Saharan Africa region, in contrast, extreme poverty declined only slowly to 42% in 2015 from 55% in 1990.

Sustained economic growth in many developing countries, particularly in Asia, is credited with a large role in global poverty reduction (World Bank 2016). In East Asia and the Pacific, China drove most of the poverty reduction, with a rapidly industrializing economy that grew by 10% annually, and created millions of jobs every year. The jobs benefited not only urban workers, but also rural workers and their households, via internal migration. Extreme poverty in China dropped from 66% in 1990 to only half a percent by 2016.

People with lower education, who live in rural areas, work on farms, and are part of big households are still over-represented among the poor (Dugarova and Gulasan 2017; World Bank 2020b). Despite rapid urbanization in most developing countries, poverty is still predominantly a rural phenomenon, accounting for nearly two-thirds of total national poverty.

In the Philippines, poverty reduction in the three decades preceding the COVID-19 pandemic was slow compared to the rest of East Asia and the Pacific—particularly Indonesia, Thailand, and Vietnam. The proximate reasons for this low rate of poverty reduction were the country's comparatively slower economic growth, high population growth, and high inequality in the distribution of incomes and opportunities. Indeed, what was peculiar in the Philippine case was the country's relatively weak response of poverty reduction to economic growth, even after controlling for the level of economic growth (Balisacan 2019).

Prior to the COVID-19 crisis, it was estimated that global extreme poverty could be halved and, possibly, eliminated by 2030, if developing countries maintained recent per capita income growth and the growth was shared broadly across the population (Granoff et al. 2015).

But with the COVID-19 crisis, an additional 110 to 150 million people worldwide could be pushed into extreme poverty in 2020 and 2021, which will raise extreme poverty incidence by as many as four percentage points by 2030, compared to the no-pandemic scenario (World Bank 2020b). In East Asia and the Pacific, extreme poverty is projected to increase by 5 million to 9 million people in 2020.

Separately, the World Bank (2020b) estimates that climate change could potentially raise global extreme poverty by 68 to 132 million people by 2030, depending on the scope and severity of the climate-change impacts.

The channels through which climate change are expected to impact poverty are agricultural productivity, food prices, natural hazards, the effect of extreme temperature on outdoor workers' productivity, and health issues (World Bank 2020b). Some forecasts are even bleaker, such as the Overseas Development Institute's forecast of 720 million more poor between 2030 and 2050 because of climate change (Granoff et al. 2015).

Moving forward, it is expected that there will be greater focus on multidimensional poverty, which looks not only at income poverty but also at lack of access to education (attainment and enrollment), health (longevity), and basic infrastructure (electricity, connectivity, sanitation and drinking water). Here as well, progress has been uneven across countries and across dimensions.

According to the World Bank (2020b), circa 2017, the multi-dimensional poverty headcount ratio was at 14%, and deprivation was relatively still high in sanitation and educational attainment, especially for Sub-Saharan Africa and South Asia. East Asia and the Pacific scored poorly relative to other regions (except Sub-Saharan Africa), in access to safe drinking water.

Economic Inequality

Some caveats on availability and quality of data limit the precise measurement of income and wealth inequality, and how they have moved over time. But some studies find that income inequality has significantly declined among countries but risen within countries in the past 25 to 30 years (Bourguignon 2017; Milanovic 2018).

The decline in inequality among countries has been attributed to rapid economic growth in some developing countries with very large populations, especially China and India, and their rapidly expanding middle classes (Milanovic 2018).

Meanwhile, income inequality within-country was found to have increased compared to a quarter of a century before in the majority of developed countries and some of the largest developing countries, in particular, again, China and India, but also Indonesia (Bourguignon 2017).

Atkinson et al. (2011), using historical income tax data, found that the income share of the top one percent in many developed countries has substantially gone up over the previous three decades. Dugarova and Gulasan (2017) further argue that if the rise in inequality within-countries continues, it could possibly raise global inequality again.

The factors that have been identified to have exerted significant upward pressure on inequality are tax policies that favored the rich, globalization, and skill-biased technology that disproportionately benefited those with higher skills, and those who had higher income or wealth in the first place (Alvaredo et al. 2013; Bourguignon 2017; Milanovic 2018; World Bank 2020b).

On the other hand, where inequality has declined, the factors that were found to have contributed to the decrease were public transfers, progressive taxation, and minimum wage policies (Dugarova and Gulasan 2017). The quality of economic growth has been found to matter as well, i.e., whether it creates many jobs or not, and who have access to those jobs, in determining the impact of economic growth on inequality.

The COVID-19 crisis could exacerbate income inequality, as it pushes firms to rapidly automate to minimize risks and reduce demand for low-skill and typically lower-income workers (Stiglitz 2020). Given that the pandemic has forced schools to shift to remote learning, which disadvantages students with poor digital access, or who go to schools which are ill-equipped for such a shift, and whose parents lack the education or skills to provide home learning—all likely to be students from low-income households to begin with, its impact can be long-term and even intergenerational.

On the one hand, the digital economy has been a growth accelerator for smaller businesses. On the other hand, it may increase inequality should essential digital platforms further weaken workers' bargaining power. As evidence indicates, rising inequality can disrupt social cohesion and breed socially unproductive rent-seeking activities. This disruption and economic waste tend to undermine the sustainability of economic growth.

Governments have tools at their disposal to tame inequality, moving forward. Granoff et al. (2015) sum up the key areas for interventions:

(a) boosting the human capital of the poor
(b) allowing the poor to accumulate assets
(c) improving pro-poor infrastructure and services
(d) increasing employment opportunities for the poor
(e) enhancing governance and political representation

Milanovic (2018), meanwhile, has made the case that global inequality (and poverty) can be further reduced via a more open labor migration policy.

Science, Technology, and Innovation as Enabler

STI play a key role in addressing the various dimensions of poverty and the highly inequitable distribution of opportunities in the Philippines. If harnessed well, STI can open up economic opportunities for the rapidly growing labor force, improve population mobility and human capital especially for the less well-off families, and mitigate and prevent the adverse effects of climate change, and advance institutions and governance toward shared prosperity.

Specifically, STI can make food and health systems more efficient, sustainable, and accessible to all, particularly the poor. It is key to solving the current health crisis and preventing future ones. Cleaner and more sustainable energy, water, and transport technologies will also enhance conservation efforts and prevent further environmental degradation. STI will also create more adaptable shelters, transportation systems, and other physical and digital infrastructure, which will not only protect vulnerable populations, but will also make the economy more resilient to future natural hazards.

Realizing the potentials of STI as an enabler of the economy and of society demands the government's strong commitment to mainstream STI effectively in the nation's vision, plans, and policy implementation for long-term growth and development (see also Section 3).

SECTION 2.2
CLIMATE CHANGE AND EXPLOITATION OF NATURAL RESOURCES: POLLUTION, GLOBAL WARMING, AND INCREASE IN EXTREME WEATHER EVENTS

Nature is vital to the achievement of the interconnected Sustainable Development Goals (SDGs) related to poverty, hunger, health, water, cities, climate, oceans, and land (SDGs 1, 2, 3, 6, 11, 13, 14, and 15). However, the current negative trends in biodiversity and ecosystems will most likely derail the progress towards achieving 80% of targets of SDGs (UNCCD 2017).

Planetary scale challenges came to the fore in the last couple of decades. There is an increasing realization among scientists and policymakers that the current trajectory of "development" is unsustainable. While rising gross domestic products (GDPs) are being recorded in many countries, natural ecosystems are being modified and natural resources are being depleted at unprecedented rates. This is manifested in worsening air quality and increasing air temperatures in most countries of the world, including the Philippines. Poor air quality is common in many large urban areas and air temperatures have been on upward trend for the last few decades.

Air Pollution

One of the negative impacts of economic development and urbanization is increasing air pollution. As might be expected, Metro Manila is the most polluted area in the Philippines. Based on a national emissions inventory conducted by the Environmental Management Bureau (EMB) in 2015, the majority (65%) of air pollutants in the country originated from mobile sources, such as vehicles. About 21% and 14%, were from stationary sources (e.g., power plants) and area sources (e.g., open burning of solid wastes), respectively, about 88% of air pollutants are from mobile sources with 10% from stationary sources and 2% from area sources. The major pollutants from mobile sources are volatile organic compounds and carbon monoxide, gases such as sulfur oxides and nitrogen oxides from stationary sources, and particulate matter from area sources (DENR-EMB 2019).

The main piece of legislation addressing air pollution is RA 8749, or the Clean Air Act. In compliance with the law, the EMB has implemented the following:

- Designation of airsheds throughout the country.
- Establishment and operationalization of the Air Quality Management Fund.
- Establishment of Ambient Air Quality Monitoring Network nationwide.
- Emissions inventory every three years.
- Management of mobile and stationary sources.

Climate

Rainfall. The country's rainfall pattern varies according to geographical location, as well as seasons. Since the 1950s, the total annual rainfall has increased in areas like Central Luzon, while it has declined in Northern Luzon (Figure 2.2_1). Extreme rainfall has declined in most parts of the country.

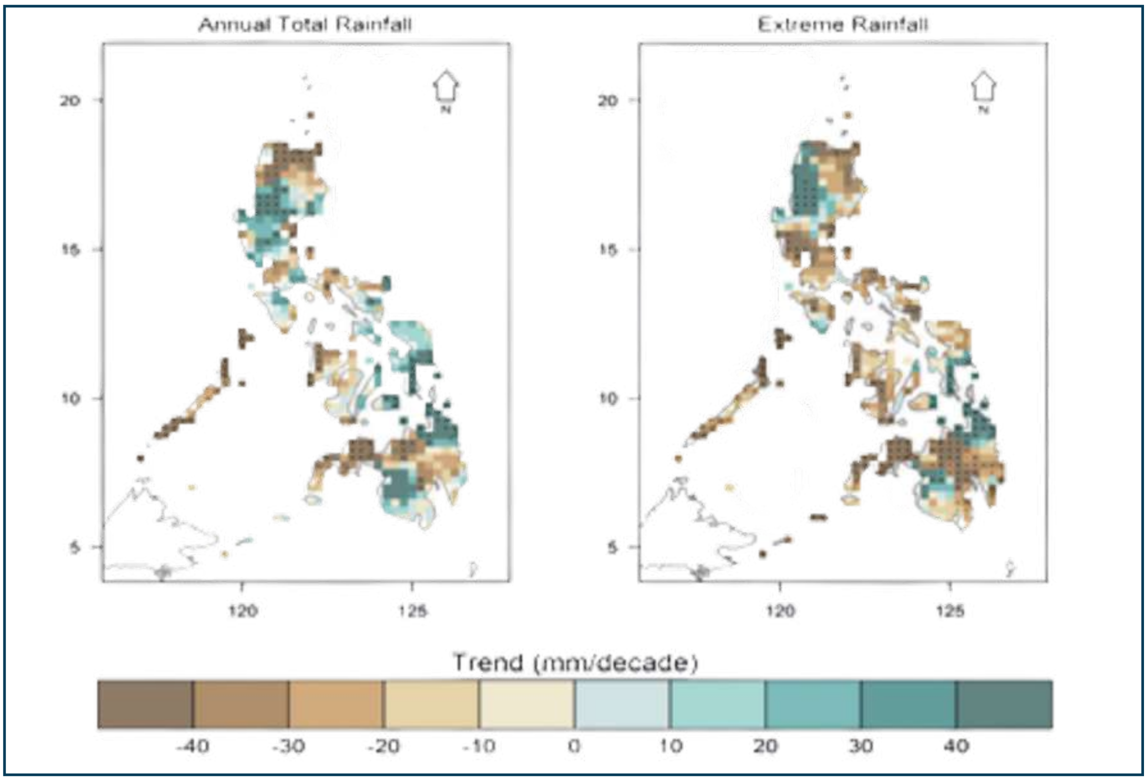


Figure 2.2_1. Observed Trends in Annual Total Rainfall and Extreme Rainfall in the Philippines during the period 1951-2010.

Source: PAGASA (2018)

Air Temperature. The country's air temperature has been steadily warming, with an average increase of 0.68°C over the past 65 years (Figure 2.2_2). This is consistent with the global warming trends, which have been attributed to the rise of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Since the start of the industrial revolution, average global temperature has risen by about 1°C (IPCC 2018).

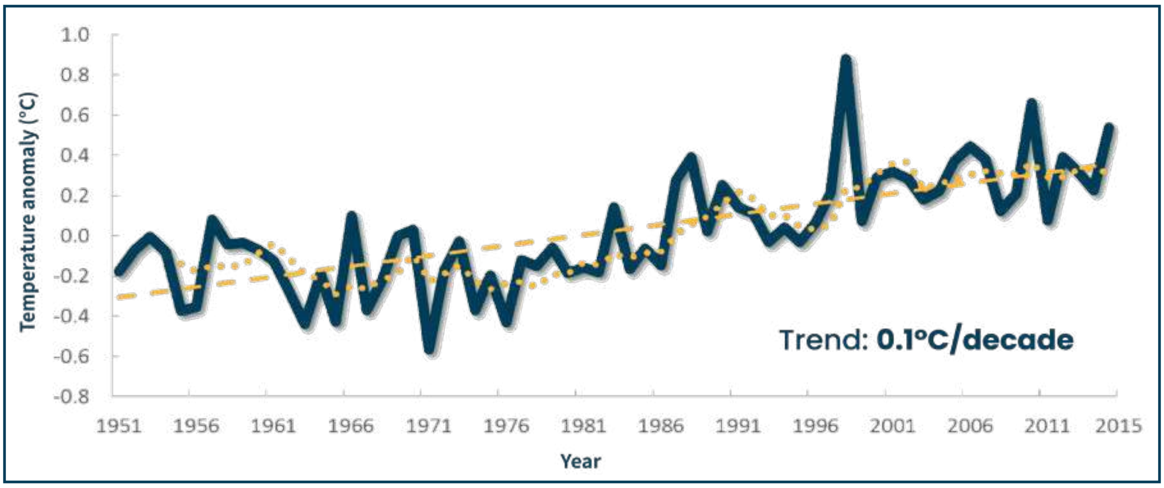


Figure 2.2_2. Air Temperature Anomaly in the Philippines from 1951 to the Present.
Source: DOST-PAGASA (2018)

Extreme Weather Events. While there are no significant differences in the number of tropical cyclones entering the Philippines and making landfall since 1951 (Figure 2.2_3), there has been a minimal increase in the number of tropical cyclones with maximum winds of more than 170 kph (DOST-PAGASA 2018).

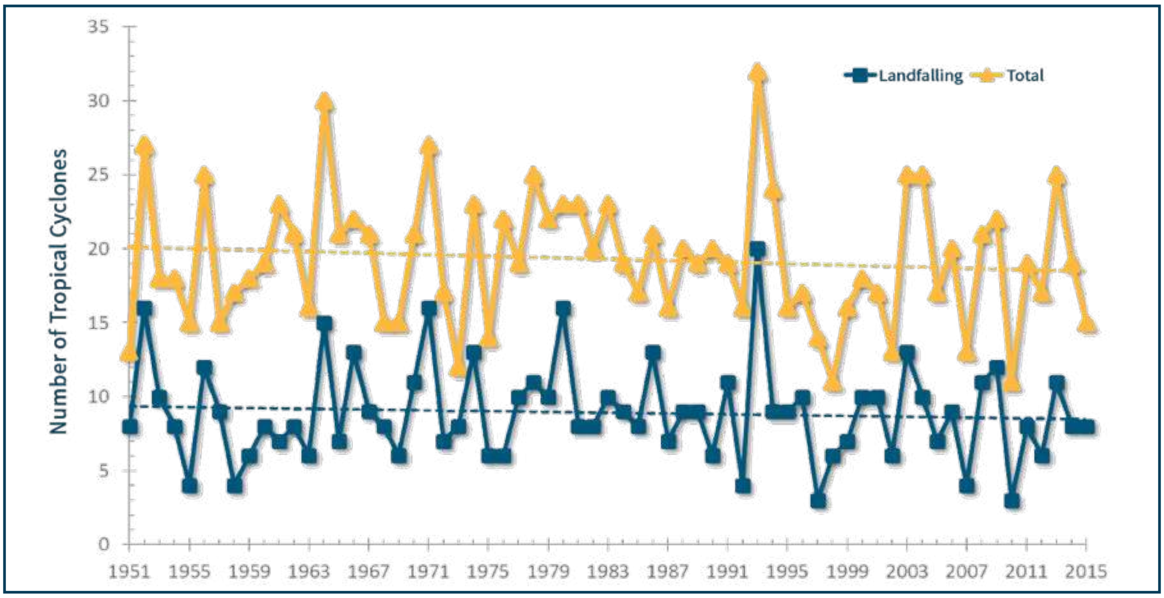


Figure 2.2_3. Annual Number of Tropical Cyclones in the Philippines from 1951 to 2015.
Source: DOST-PAGASA (2018)

Adaptation to climate hazards. The Climate Change Commission (CCC), the Department of Environment and Natural Resources (DENR), the Department of Science and Technology (DOST), and the Office of Civil Defense are the key government agencies addressing the climate hazards. Other departments are also addressing climate change impacts on their plans and programs.

There are numerous adaptation practices and technologies available for minimizing the impacts of climate hazards. For example, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) has steadily improved its capability to forecast tropical cyclones and heavy rains through the use of computer simulations and radar technology. The CCC has launched education campaigns to inform the public of the dangers posed by global warming.

Land State and Trends of Global and Sub Global Terrestrial Natural Resources

Land is a principal resource on which biodiversity, livelihoods, supply of food, freshwater and other ecosystem services, depend. Use of land for various activities directly affects more than 70% of the global, ice-free land surface (IPCC 2019a). Land also plays an important role in the climate system being a source and a sink of greenhouse gases (GHGs) and plays vital roles in the exchange of water, nutrients and aerosols between the land surface and the atmosphere (IPCC 2019a). Figure 2.2_4 shows how land productivity is influenced by land use change largely associated with forestry, agriculture and urban development (UNCCD 2017).

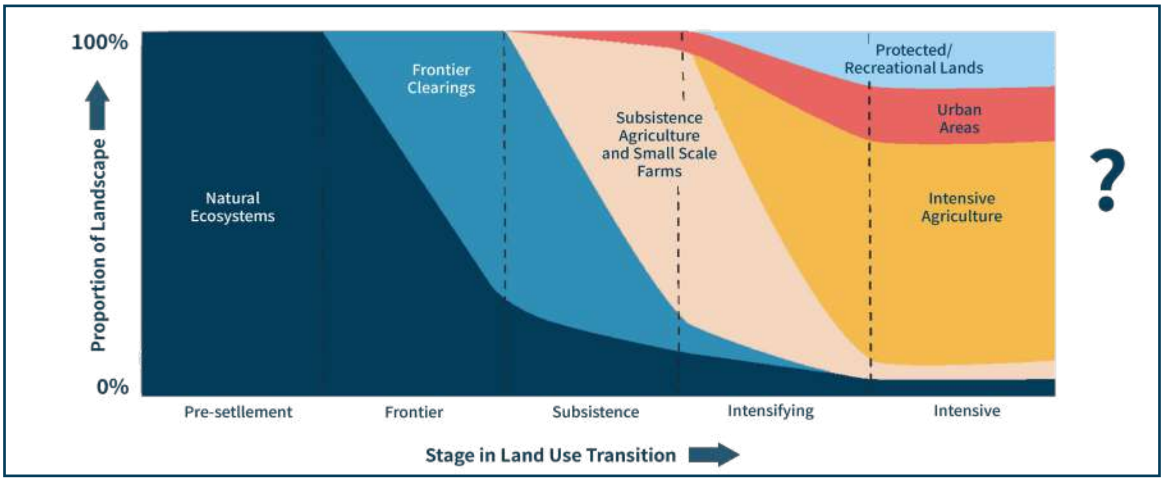


Figure 2.2_4. A Time Graph Showing Typical Changes in Land Use due to Human Settlement and Expansion.
Source: Jägermeyr et al. (2017)

Specifically, land use change is largely driven by tropical deforestation and agricultural expansion, temperate reforestation or afforestation, cropland intensification and urbanization (Song et al. 2018). Among these, agricultural expansion is the most widespread form of land-use change, with more than a third of the global land surface being used for agriculture (UNCCD 2017).

Between 25% and 33% of the land's potential net primary production is already being used for food, feed, fiber, timber, and energy. One study estimated the total annual value of the world's terrestrial ecosystem services is approximately equivalent to the annual global GDP (IPCC 2019a). Land use has also been linked to the emergence of bat-borne Nipah virus in Malaysia, cryptosporidiosis in Europe and North America, and a range of food-borne illnesses globally.

Increasing tropical deforestation, along with infrastructure and urban development, modifies natural habitats and the transmission of infectious diseases such as malaria in Africa, Asia, and Latin America. In addition, disturbance of wildlife habitats is a growing concern, since 75% of human diseases have links to wildlife or domestic animals (Foley et al. 2005).

Forests. The total forest area of the world is 4.06 billion hectares, which currently roughly translates to 0.5 ha per person. Forest area as a proportion of total land area (SDG Indicator 15.1.1) decreased from 32.5% to 30.8% between 1990 and 2020 representing a net loss of 178 million hectares of forests.

However, the average rate of net forest loss declined by roughly 40% between 1990–2000 and 2010–2020 (from 7.84 million ha per year to 4.74 million ha per year), the result of reduced forest area loss in some countries and forest gains in others (FAO 2020). Given this, the world is not on track to meet the target of the United Nations Strategic Plan for Forests (UN 2017) to increase forest area by 3% worldwide by 2030 relative to 2015 (FAO 2020). In large parts of the biodiverse tropics, 32 million hectares of primary or recovering forests were lost between 2010 and 2015 (IPBES 2019).

The extent of tropical and subtropical forests is increasing in some countries but is decreasing in others, while the global extent of temperate and boreal forests is generally increasing. The continuing decline of tropical and subtropical forests in some countries is driven by economic development, technological and demographic factors, expansion of agriculture, grazing and urban development. Among these drivers, agricultural expansion is the most influential (Annunzio et al. 2015; FAO and JRC 2012). About 70%-95% of forests loss in the tropics are due to conversion to agriculture (Holmgren 2012).

Forests play a vital role in the mitigation of climate change by sequestering carbon and storing it in biomass form. Forests absorb 2.6 billion tons of carbon dioxide each year, about one-third of the carbon dioxide released from the burning of fossil fuels (IPCC 2014).

On the other hand, deforestation is one of the major sources of GHG emissions, contributing around 20% of the total GHGs in the atmosphere. Conversely, climate change is one of the significant drivers of forest degradation and deforestation. Most of the drier regions of the world experience reduction in forest cover due to increased forest fire occurrences, outbreaks of pests and diseases triggered by excessive warming and drying. In other regions, climate change positively contributes to enhancement of forest growth and expansion of forest cover due to increase in precipitation and carbon fertilization.

Sustainable forest management, forest landscape restoration, and forest law enforcement are proven strategies for keeping forests healthy and resilient, and to restore degraded forests and deforested areas to their multifunctional state. Healthy forests help reduce GHGs in the atmosphere through carbon sequestration while, at the same time, providing a variety of services essential to a secure, progressive, and resilient people.

Biodiversity. Biodiversity is one of the pillars of sustainable ecosystems, because of their ability to provide an array of services that are essential to a progressive and secure society. However, global biodiversity is under siege by combined pressures from land use change, climate change, pollution, and invasive alien species (IPBES 2019). Land use change is mainly driven by agricultural expansion and overexploitation, and to a lesser extent by tree plantation development, grazing, and human settlements that lead to deforestation, and forest degradation and fragmentation (Figure 2.2_4). Climate change-induced disasters and other disasters due to natural hazards also cause forest fragmentation.

Consequently, the average abundance of native species has declined by at least 20% in most major terrestrial biomes with potentially harmful impacts on ecosystems and their services rendered to people. Most of this decline began in 1900 and is likely accelerating. Native biodiversity in areas of high endemism has often been negatively affected by invasive alien species. Populations of wild vertebrate species have tended to decline over the last 50 years on land, in freshwater, and in the sea (IPBES 2019). On average, species continue to move closer to extinction. Nearly 25% of species of well-assessed taxonomic groups totaling one million species are threatened with extinction unless the drivers of biodiversity loss are significantly reduced.

Wild animal populations have shrunk by more than two-thirds since 1970, and have continued to decline since 2010. The number of extinctions of birds and mammals would likely have been at least two to four times higher if conservation actions were not taken over the past decade (UNCBD 2020). Significant progress has been achieved in improving the understanding of the biosphere since 2010 through progress in the generation, sharing, and assessment of knowledge and data on biodiversity, big-data aggregation, advances in modelling, and artificial intelligence. However, major imbalances remain in the location and taxonomic focus of studies and monitoring. Information gaps remain in the consequences of biodiversity loss for people, and the application of biodiversity knowledge in decision making is limited.

Agriculture. Most of the arable lands of the world are already in use. However, there are still sufficient land resources that can be developed and made productive with the provision of adequate resources and reversal of the neglect in agricultural research and development in recent decades (FAO 2009). The challenge is that the remaining land resources that can be developed are unevenly distributed across the world.

Agricultural crop production has increased almost threefold since 1970 and was valued at USD 2.6 trillion in 2016. Currently, productivity in 23% of the global terrestrial area has been reduced by land degradation that puts at risk between USD 235 billion and USD 577 billion in annual global crop output due to pollinator loss (IPBES 2019). Infrastructure and urban development already cover 60 million ha (UNCCD 2017) and are likely to have encroached into crop lands. Soil erosion and drought are also significant causes of agricultural land degradation, and this is exacerbated by climate woes.

Soil. The likely range of global soil erosion by water is 20 to 30 gigatons per year while tillage erosion is about five gigatons per year. Rates of wind erosion are highly uncertain with around 430 million ha of drylands being particularly susceptible. Erosion rates on hilly croplands in tropical and subtropical areas may be as high as 50 to 100 tons per ha per year, with a global average of 10-20 tons per ha annually (FAO and ITPS 2015).

Major impacts of soil erosion include loss of soil fertility, siltation of rivers, lakes, farms, coastal and marine areas, and water quality degradation. Soil loss, which is rich in soil organic carbon is also a major source of GHG emission that fuels climate change (FAO and ITPS 2015). Conversely, climate change is a major factor of soil loss by enhancing rainfall in areas with lots of rainfall, and by impinging on water supply in dry areas where rainfall is decreasing.

Timber. There is sufficient global timber supply from industrial forests of about 1.2 billion ha half of which is in high-income countries and only 8% in low-income countries (UNCCD 2017). Up until 2005, global forest plantations have been increasing, with the largest increase taking place in Asia, among the major timber producing regions in the world.

Expansion of global forest plantation from 1990 to 2005 is projected to sufficiently meet the growing global demand for timber that is expected to more than triple in 2050 compared to 1990 estimate (Ince 2010; Cuong et al. 2020). In 1990, forest plantations in Asia covered around 29 million ha which increased to approximately 45 million ha in 2005 (Ince 2010). The expansion of forest plantation in Asia is, however, uneven across sub-regions, with the largest expansion taking place in East Asia, courtesy of the aggressive plantation development program of China. In some countries of Southeast Asia like Vietnam, the increase in forest plantation has also been remarkable, and is attributable to strong national and local government support.

Most tropical forests are still not managed sustainably (UNCCD 2017). Given that the right policies and governance mechanisms are put in place, sustainably managed natural forests could provide additional sources of timber in the future.

Global Status and Trends on Coastal and Marine Resources

The oceans cover more than 70% of the earth's surface and form the largest life-support system of the planet. The ocean also provides various ecosystem services. It nurtures biodiversity; stores carbon and stabilizes the climate. It directly supports human well-being through food, minerals and other industrial materials, energy resources; and cultural and recreational services.

The contribution of ocean-based industries to economic output and employment is very significant. In 2010 this was valued very conservatively at USD 1.5 trillion, or approximately 2.5% of world gross value added. Direct full-time employment in the ocean economy amounted to around 31 million jobs in 2010. The largest employers were industrial capture fisheries, with over one-third of the total and one-quarter from maritime and coastal tourism. Growth of these industries is expected to accelerate.

The Organization for Economic Cooperation and Development estimates that, by 2030, USD 3 trillion will be generated annually from ocean sector industries. Ocean industries are anticipated to employ approximately 40 million full-time equivalent jobs. Strong growth is expected in marine aquaculture, offshore windmills, fish processing, and shipbuilding and repair (OECD 2016).

Given the rapid development, scaling-up and diversification of uses of the oceans on the one hand, and the deteriorating health of the ocean on the other, a holistic "blue economy" approach has been put forward by the international community to consider the health of the oceans and seas, and to balance the three dimensions of sustainable development: economic, social and environmental (UN 2016a). This new paradigm of ocean economy, balances the long-term capacity of the assets, goods and services of marine ecosystems, and considers social inclusiveness (World Bank and UNDESA 2017).

Key Drivers and Impacts. The expansion of economic activities in the ocean is driven by the increase in global population, economic growth, and advancements in technology. Technological advancements over the past decades have rendered even the most remote parts of the ocean accessible—including discovery of new, valuable resources in the deep seabed. The intensification of the use of the oceans will further threaten the already poor health of the oceans and, thus, the long-term sustainability of the ecosystem services from the sea.

Development in coasts and oceans are impacted by activities related to acquisition of food, materials and use of space for various activities. The coasts and nearshore waters are also very vulnerable to land-based pollution, in particular agricultural run-off, chemicals, and macro- and micro-plastic pollutants that feed into the ocean from rivers.

Climate change has encompassing impacts, given the strong interaction between oceans and atmosphere. Resulting environmental changes (increase in temperature, sea level rise, ocean acidification) will directly affect the spatio-temporal patterns of biotic (e.g., distribution and abundance of biodiversity including fishery resources) and abiotic resources (e.g., energy sources—temperature, wind) and human activities at global and regional scales.

Source of Food. With the increase in global population, food demand is also rising. Food from the sea has an important role in food security and global supply. Production from the wild fisheries and farmed species in the ocean accounts for 17% of the global production of edible animal protein (Costello et al. 2020).

However, exploitation of fishery resources has exceeded sustainable levels in many regions. The decline in the productivity of the oceans is further exacerbated by pollution and climate change (Barange et al. 2018). Likewise, the expansion of marine aquaculture (mariculture) production to supplement production for seafood is constrained by climate change and concerns on sustainability given the new or increased pressures on marine ecosystems, i.e., aside from pollution, infectious diseases and the related emergence and spread of drug-resistant pathogens (Reverter et al. 2020).

Source of Raw Materials. Apart from living resources for food, the ocean encompasses a wide range of biotic, abiotic, and intangible resources (Jouffray et al. 2020). Marine organisms are sources of raw materials for industries other than for food (e.g., seaweed derived products, ornamental trade). Moreover, with the advent of biotechnology and technologies for the exploration of the deep sea, access to marine genetic resources from areas beyond nation jurisdiction (ABNJ), which include vast areas of the deep sea—including poorly-known habitats (hydrothermal vents, sea mounts) with unique assemblages of organisms, are currently hotly contested. Recognizing the legal gap in managing resources in ABNJ, an international legally binding treaty was developed under the United Nations Convention on the Law of the Sea (UNCLOS) (Rabone et al. 2019).

Of the abiotic resources, the oil and gas sector is the largest ocean-based industry. Nearly 70% of the major discoveries of hydrocarbon deposits between 2000 and 2010 happened offshore, and as shallow-water fields become depleted, production is moving toward greater depths. Aside from exploration and exploitation of hydrocarbons, the prospects for vast quantities of natural gas hydrates as well as rich mineral resources in deep-sea mining has propelled unprecedented expansion from exploration to exploitation.

Contractors' interest in claiming large tracts of seafloor with exclusive rights for exploration increased from just eight in the first four decades (1970–2010) to 25 in the next four years (2011–2015) (Sharma 2017). The International Seabed Authority (ISA), was established in 1992 to regulate human activities on the deep-sea floor beyond the continental shelf.

To date, 27 contracts for mineral exploration have been granted, encompassing a combined area of more than 1.4 million sq km. However, many of the regions identified for future seabed mining are already recognized as vulnerable marine ecosystems (Miller et al. 2018).

Space for Various Uses. Infrastructure to support extraction of food and materials such as fishing boats, aquaculture farms, offshore platforms and deep-sea mining equipment, all require space in the ocean. However, the ocean space also provides the basis for a multitude of other activities at sea such as shipping, pipelines and cables, renewable energies, conservation, tourism and recreation, reclamation, territorial boundaries and associated military activities. Exploitation of Natural Resources and Climate Change

The phenomenal rate of change of activities for extraction of food and materials and the diversified need for space over the past 50 years, with a sharp acceleration at the onset of the 21st century, are intensifying the pressure on the ocean and leading to a range of synergistic, antagonistic, and additive interactions between these different uses (Jouffray et al. 2020).

Mitigating Measures and Opportunities. The diverse uses of coast and ocean resources, and the dynamic spatio-temporal changes affected by anthropogenic factors as well as natural factors, emphasized the need for better governance systems for human activities in the ocean space at all scales of governance from global to the local. Several of the interlinked UN SDGs are essential in relation to the ocean and seas, Goal 14— 'Life below Water' —specifically addresses marine issues (UN 2016b).

An **Integrated Ocean Management** (IOM) is the overarching framework for a holistic, ecosystem-based, and knowledge-based approach meant to ensure the sustainability and resilience of marine ecosystems and coastal communities. At the same time, this integrates and balances different ocean uses to optimize the overall ocean economy, as well as maintain and further develop the effective sector-based management of ocean industries.

Successful implementation of IOM requires a good understanding of different contexts, including local knowledge, environmental conditions, and scaling-up of local actions. In addition to local considerations, there are universal opportunities for action identified to help achieve IOM for a sustainable ocean economy as follows (Winther et al. 2020):

- harness science and knowledge
- establish partnerships between public and private sectors
- strengthen stakeholder engagement and stewardship
- improve capacity-building
- implement regulatory frameworks
- encompass climate change and other environmental changes in adaptive management system.

SECTION 2.3
NAVIGATING THE NEW GLOBALIZATION: THE PHILIPPINE PERSPECTIVE

Deep structural "mega-trends" have been sweeping across the world, notably the emergence of a new era of "digital globalization". These changes promise to re-shape international economic linkages, just like the previous waves of globalization relating to trade, finance, and people. This new globalization is linked to the 4th industrial revolution, which sees automation, artificial intelligence, the internet of things (IoT), and other technological trends not just reshaping the world economy, but also creating disruptions and spurring innovations in the social and political spheres.

However, the new globalization has been interrupted by the COVID-19 pandemic, which has affected over 200 countries and territories. It is crucial to understand whether the interruption will be a brief one or a mere blip. The uncertainty related to the pandemic and to certain political factors (e.g., return of populism in many economies) may point to a protracted adjustment period for broader globalization trends.

From a Philippine perspective, it is critical to understand the implications of these waves of change which are sweeping across the world.

Intended as an evidence-based foresight analysis, we map the main features of globalization and outline some initial policy directions, with a particular focus on science and technology. Its main recommendations include focusing on the Philippines' efforts at building back better from the pandemic in areas that would improve on inclusive recovery from the pandemic, and on more inclusive development during the post-pandemic period.

In addition to the COVID-19 pandemic, natural hazards also disrupted activities in the Philippines such as volcanic eruptions, consecutive strong typhoons, earthquakes, and other phenomena that might be related to climate change. More science-based support is recommended to pre- and post-disaster initiatives to mitigate risks, minimize losses, and strengthen the adaptive capacity of institutions in the country.

Globalization and the Fourth Industrial Revolution

Globalization has been a double-edged sword: it provided opportunities for innovation, economic development, and transformation of political communities, but also caused disruption and human suffering for some groups through diseases, conflicts, and financial crises (Sachs 2020).

The initial phases of globalization were characterized by the movements of people, goods, and finances. This is now shifting to the soaring flows of data worldwide—a phenomenon called "digital globalization" (McKinsey Global Institute 2016). After almost four decades of steady increases in global trade as a share of gross domestic product (GDP), the 2008 international financial crisis triggered a slowdown.

In 2019, global trade was at 60.4% of world's GDP, close to the 60.8% estimate before the 2008 crisis. When one examines the flows of goods, services, and finance as an aggregate (and as a share of world GDP), there has been tapering off since 2010. We expect this to remain this way or drop even more during the pandemic (Figure 2.3_1).

The Fourth Industrial Revolution (FIRe) fuses the physical, digital, and biological domains through technology, embedding it not only within societies but also in the human body (Schwab 2016). The FIRe is characterized by breakthroughs in artificial intelligence, nanotechnology, biotechnology, three dimensional (3D) printing, and the internet of things (IoT) among other spheres (Schwab 2016).

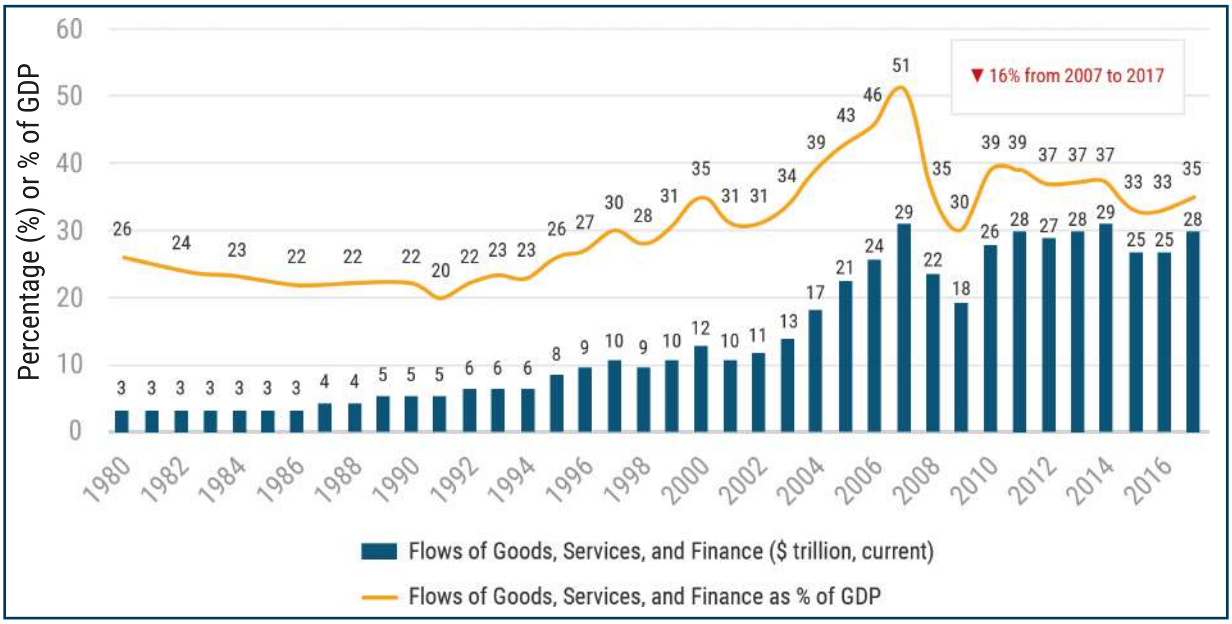


Figure 2.3_1. Flows of Goods, Services, and Finance as % of GDP.
Source: McKinsey & Company (2018)

Cross-border data flows further fuel trade and investments across countries, creating new areas for productivity enhancement and wealth creation. McKinsey Global Institute (2016) notes: "The amount of cross-border bandwidth that is used has grown 45 times larger since 2005. It is projected to increase by an additional nine times over the next five years as flows of information, internet searches, online communications, video, online transactions, and intracompany internet traffic continue to surge. In addition to transmitting valuable streams of information and ideas in their own right, data flows help to facilitate the movement of goods, services, finance, and people." (Figures 2.3_2 and 2.3_3) Virtually every type of cross-border transaction now has a "digital component". Yet these, too, raise new challenges, as the benefits of digital trade are premised on trust, which raises issues of regulation to protect privacy, consumer welfare, and secure data management (Casalini and Lopez Gonzalez 2019).

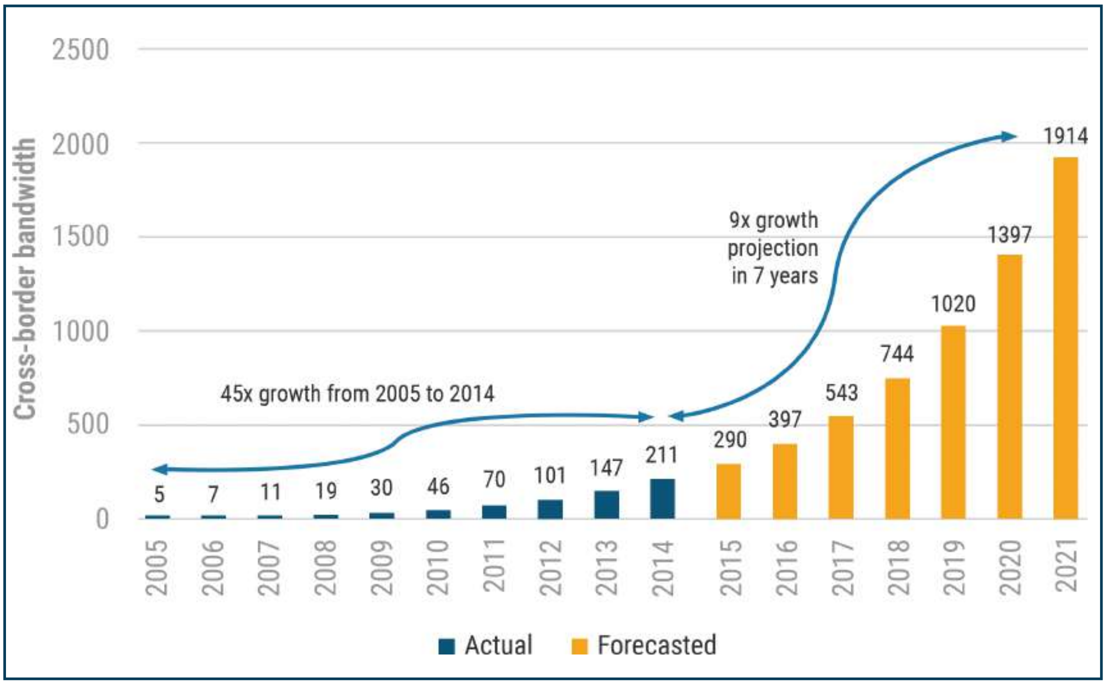


Figure 2.3_2. Cross-border Bandwidth Growth Data
Source: McKinsey Global Institute (2016)

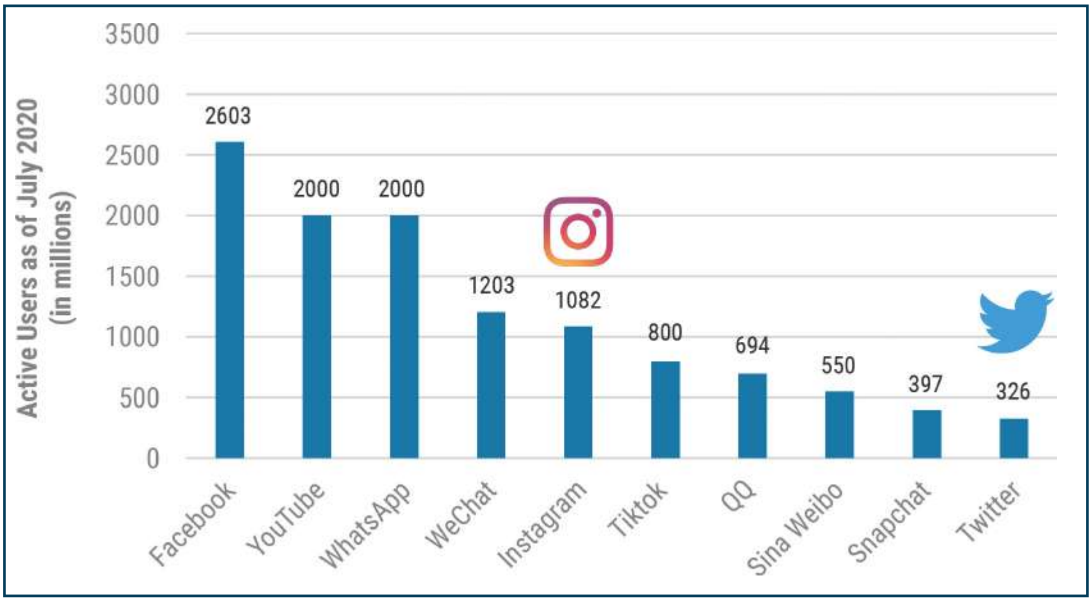


Figure 2.3_3. Digital Platforms Interconnecting People and Firms Across Borders.
Source: Statista (2020)

Across countries, there is wide variance in institutional readiness to underpin this trust. Within countries, and across firms, there is also wide variance in online access networks. In other words, the contours of this round of globalization are not as “flat” as previous eras—uneven governance and institutional quality, and disparate access to technology across and within countries augur less equal participation in this globalization round. Yet, clearly, the impact will be felt worldwide whether a country participates or not.

In the post-COVID-19 world, it is more likely that this part of international trade will increase further and faster, fueled in large measure by online connectivity that has become more important under lockdown conditions. Analysts predict that consumer behavior may have begun to permanently change under the “new normal”, with e-commerce within and across borders playing a much larger economic role.

While most developed countries are already adapting to the changes brought by the FIRe, the situation will be different for developing countries like the Philippines. According to the Readiness for the Future Report of the World Economic Forum, the Philippines is classified as a “legacy country”, which means a strong production capacity is present in the country (WEF 2018a). However, the Philippines is also at risk of future shocks due to its weak institutional framework, human capital, and innovation capacity.

Some aspects of the FIRe are already present in the country, with several industries and government instrumentalities adopting technologies to expedite processes and supplement capabilities. For instance, the Armed Forces of the Philippines used drones for surveillance and reconnaissance during the Marawi Siege in 2017, which helped in their operations (Franco 2017). 3D-printing is also on the rise—the first 3D-printed hotel was erected in 2015 in Angeles City, Pampanga (Tablang 2015). In terms of financial technology, platforms such as GCash have over 20 million registered users and 63,000 partner merchants nationwide, making financial transactions more efficient for Filipinos (Philippine Daily Inquirer 2019).

Unequalizing Trends: From ‘Flat World’ to ‘Regional Trade, Tourism, and Investment Bubbles’

The COVID-19 pandemic has interrupted globalization, and it may have erected additional economic, political, and health challenges for many countries, increasing the possibility that there will be varied progress in establishing the conducive institutional frameworks for fully engaging in the FIRe.

Rather than multilateralism, increased regionalism may become even stronger in the post-COVID-19 world, akin to the tourism and trade bubbles now being promoted as part of coping strategies for countries that band together in terms of their relative success in dealing with the pandemic (Locker 2020). Such trends may exacerbate inequality in several ways, particularly in the Philippine context.

Poverty and Hunger During the 'Great Lockdown Recession'

The social inequality among Filipinos became more pronounced as the coronavirus pandemic in the Philippines quickly shifted from a health crisis to an economic recession.

As the country was put into lockdown, thousands of businesses were forced to temporarily stop operations and, consequently, lay off millions of workers who had to rely on the government's meager financial support for their survival.

In July 2020, adult unemployment in the Philippines rose to 45.5% from 17.1% in December 2019—equivalent to 27.3 million unemployed Filipinos (SWS 2020b). While skilled workers were able to continue their employment through a work-from-home setup, less-skilled workers, especially those that perform manual labor, are the most exposed to the infection risk.

Clearly, there is an emerging divide between highly adaptive and skilled workers who can work more safely from home and maintain their productivity and jobs, and the mass number of less-skilled workers who suffer more shocks from the pandemic, and continue to face relatively higher risks under the "new normal".

The 'Matthew Effect' in Education

As part of the measures set in place by governments to contain the virus, face-to-face interactions were prohibited, which prompted schools to move their classes online. Yet, according to the National Information and Communications Technology Household Survey 2019, only 17.7% of households nationwide have their own internet access at home, and 24% have communal cellphones but only two out of 10 have communal computers (DICT 2020). The necessity to push online learning is likely to spur innovations in online education which may introduce cost-effective models that could last beyond the COVID-19 crisis. However, experts fear that the crisis is likely to exacerbate the "Matthew effect": a deepening inequality in access to education and quality of learning across the digital divide (Burgess and Sievertsen 2020; UNESCO 2020).

In addition, there is growing recognition of the necessary retooling of the education system so that countries go well beyond mere "emergency remote teaching", with key investments in both hardware (classroom connectivity) and software (notably proper teaching skills build-up). Such an education system can also be better prepared for any future pandemic, providing more options in education, with potentially fewer disruptions in learning and education outcomes.

Even without considering the digital divide, there is already an existing inequality in access to education in the country and this is evident in assessment results. In the 2018 Programme for International Student Assessment results, the Philippines scored below the average in reading, mathematics, and science among 79 participating countries from the Organisation for Economic Co-operation and Development countries (OECD 2019a). The result also noted that "socio-economically advantaged students outperformed disadvantaged students in reading by 88 score points" (OECD 2019a).

Automation and Jobs

A disease outbreak may end up accelerating many aspects of FIRe through several channels.

First, robots do not catch a colds and, in an era of global pandemics, there is a distinct advantage behind manufacturing, transport, and other systems that are less impacted by disease outbreaks and the means through which these are contained. Some analysts argue that automation is likely to have received a dramatic boost from COVID-19 (Morgan 2020). Social distancing, quarantines, travel restrictions, and lockdowns will create massive inefficiencies in the economy (e.g., a sub-optimal number of passengers in airlines, shoppers in malls, riders of mass transport, and even fewer workers in manufacturing). All of this will likely intensify the need to invest in increased efficiency-enhancing tools and technologies, possibly through big data and the IoT.

Furthermore, some of the responses for fighting COVID-19 are also drawn from the FIRe, offering a demonstration effect on how useful these new technologies are: tele-medicine, contact tracing applications, AI-powered and big-data enabled epidemiological simulations, and automation in retail, hospitals, and various other sectors (Khagram 2020).

Meanwhile, in the Philippines, even before the pandemic, analysts were already predicting that over 18 million jobs could be automated, raising the challenges of strengthening education, re-skilling for better job-matching, boosting innovation, and ample social protection and training mechanisms during the adjustment period (see among others, Albert et al. 2017; Dadios et al. 2018; and Moraje 2017).

According to the results of a survey conducted by an American consulting firm in June 2020, 80% of firms in the Philippines had ongoing digital transformation programs while 20% have not started or did not have any plans for digital transformation (Grant Thorton 2020). Among the top five industry respondents, business process outsourcing (BPOs) had the highest number of completed projects while manufacturing was one of the industries without plans for digital transformation projects. The ongoing or completed projects for BPOs were process automation (83%), data analytics (63%), and enterprise software implementation (63%), while cloud services or infrastructure migration (50%) are the projects they want to prioritize next (Grant Thorton 2020).

Analysts forecast millions of new high-quality jobs created as part of the FIRe, and the Philippines is well placed if it has an effective game-plan to compete.

The Debt Burden

As the COVID-19 pandemic dramatically impacts the Philippine economy, and given the increased reliance on debt-financed public sector responses, Filipinos will have to bear the burden of the increasing debt for the government's COVID-19 response.

According to the Finance Department, gross borrowings will reach over PhP 3 trillion in 2020, PhP 3.03 trillion in 2021, and PhP 2.32 trillion in 2022, and these borrowings will increase the country's outstanding debt to PhP 11.98 trillion in 2021 (De Vera 2020).

Although the loans can help fund the government's efforts to respond effectively to COVID-19, future generations will have to shoulder this liability. Economic growth must continue to outpace debt growth in order for the latter to be sustainable. Moreover, governance will be key so that the investments and spending do not suffer from considerable leakages.

Poor Governance and Weak Institutions

The global pandemic has disrupted many economies, yet emerging evidence suggests that the severity of its impact can be mitigated by the relative quality of the governance environment.

A novel study by Chien and Lin (2020) empirically examines the links across governance (proxied by the World Bank's Governance Indicators) and relative effectiveness in containing COVID-19 spread (proxied by daily cumulative confirmed cases) and they found evidence that: "countries with better governance had a more rapid increase but a shorter outbreak period than countries with fair or worse governance by 19.6 to 22.3 days. Most countries with better governance (84%) revealed a declining trend in COVID-19 incidence, while such a trend was less than half of fair and worse governance countries (38.5%–41.7%)" (Chien and Lin 2020). Countries like New Zealand, South Korea, Taiwan, and Vietnam are now seen to have implemented relatively effective responses to the pandemic, underpinned by strong systems and institutions, and effective leadership (Dayrit and Mendoza 2020).

While we only have prima facie evidence at this early stage, we hypothesize here that economic actors may start differentiating across governance and institutional environments, producing "bubbles" of trade, investment and tourism ties among countries (and within their jurisdictions) with similarly strong systems, excluding those without.

In terms of the quality of e-governance systems, the performance of the Philippines improved significantly from 2014 to 2016, but slightly deteriorated between 2018 and 2020. According to the United Nations (UN) E-government Development Index (EGDI), the Philippines ranked 77 out of 193 countries worldwide in 2020 (UN DESA 2020). The EGDI measures the capability of governments to maximize technology in the delivery of public services. In terms of the level of engagement of the government with citizens measured by the e-participation index, the Philippines is at the 19th rank in 2018, 48 notches higher than its 67th rank in 2016 (UN DESA 2018).

Some 93% of national government agencies in the Philippines have web presence in 2017 (DICT 2019). Websites serve as the primary e-government channel for information; automating government processes can enhance the quality of service delivery to citizens and businesses.

One modernization initiative that may produce considerable benefits is the automation of the transactions of the Bureau of Customs (BoC), which is among the most corrupt government agencies (Presidential Anti-Corruption Commission 2018). BoC received a PhP 4 billion loan from the World Bank in October 2020 for the automation of processes, which will help strengthen efficiency and improve the business environment by reducing face-to-face interactions and delays and increase accountability (Lopez 2020).

Disasters, Climate Change, and Food Security

Between 1990 and 2018, the Philippines has been affected by 565 disaster incidents, which have caused an estimated USD 23 billion in damages (Jha et al. 2018). The continual and increasing devastation brought by strong typhoons, volcanic eruptions, and earthquakes not only constitutes significant socio-economic losses but also threatens national security.

The projected climate change impacts on agricultural production in the country is alarming. Rosegrant et al. (2015) estimated that the number of people at risk of hunger will increase by 17% by 2050, per capita GDP will experience losses of 10% annually, and that the total annual cost to the country's economy could reach over USD 3.5 billion. Furthermore, reduction in fish catch due to environmental conditions, agricultural pests, disease of crops and livestock remain issues in the sector.

Science and Technology for Inclusion: The Main Ingredients for Policy Foresight

From a mapping of the policy context, there are additional factors to consider in crafting a foresight strategy on technology and development.

First, globalization has been interrupted, and it is critical to understand whether this will be a brief interruption or a mere blip. Due to the factors related to COVID-19 and, perhaps, also the political environment (e.g., populism), this may be a more protracted adjustment period for broader globalization trends (Neuman 2020).

Second, in the immediate future, Asia and key large countries like China, India, and Indonesia will be important, not just because of their economic and population sizes (and their large emerging middle classes), but because of the important role they play in the global economy (ADB 2020a). Nevertheless, geo-political risks also suggest that there could be some challenges ahead for the region (McKinsey Global Institute 2016; Bisley 2020; Goto 2020; Oxford Economics 2020).

While there was still uncertainty due to COVID-19 at the time this was written, reformists should not be deterred from exercising bold foresight in building the necessary elements for successful recovery from COVID-19 and the lockdown recession, while also thriving under the mega-trends characterizing the FIRe.

The FIRe is fast progressing in the physical, digital, and biological domains and challenging the ability of nations and societies in managing the emerging technologies. The scale and scope of the transformation is just starting to be understood especially on how they will impact on systems of production, management, and governance (Schwab 2016).

The disruptive technologies that have been identified by the US Council on Competitiveness (2018) -

- biotechnology
- sensorization and internet of things
- big data
- artificial intellegence
- autonomous systems
- nanotechnology and new materials

will certainly have an impact on expectations of customers, on new and improved products, on collaborative innovation and on organizational systems (Schwab 2018). Also, there is an increasing investment in Space Science and Technology coming both the public and private sectors in several countries. These are all discussed in more detail in the section on operational areas of this Foresight report.

The FIRe offers new opportunities to create new wealth. It is therefore imperative that policies be instituted so that the manner of governance will fit the modes of creating new wealth. Policies must promote sustainable development, resilience, and competitiveness. Furthermore, a more open economic environment will be crucial to helping facilitate investments into the Philippines that carry with them the potential for new technology, hence increased productivity and employment opportunities.

In view of these rapid and disruptive developments in science, technology, and innovation, we need to have the numbers and quality of human capital in STEM (Santiago et al. 2008), access to universal healthcare, capacity for resilience during disasters, access to internet as a public good, and institutions to facilitate technology transfer.

We need to institute policies that will maintain the knowledge infrastructure that facilitates the seamless flow of information in the National Innovation System including market opportunities for Philippine products. In this regard, the active participation of the micro, small, and medium enterprises must be assured. An assistance system must be set up to guide the sectors of the economy as they adopt new production technologies, produce new products that can compete in the global market. The technological choices that will be made by the Philippine government and private companies must be consistent with our participation in the global effort to mitigate climate change and our commitments to the UN Sustainable Development Goals.

Lastly, the greatest societal concern would be the growing inequality that may result from the Fourth Industrial Revolution especially those who may not have access to physical and intellectual capital (Schwab 2016).

Conclusion

To ensure that the Philippines can reap the benefits of the FIRe, the government needs to increase and protect investments in human capital by building a more crisis-resilient and inclusive healthcare system, and equipping the vulnerable population with STEM education, as well as specialized education to combat disinformation.

Government needs to be agile and innovative in creating new livelihood opportunities as the disruptive forces in the economy start to operate. Leveling the playing field should be accompanied by opportunities to earn a decent living.

Lastly, barriers in technology adoption among businesses and populations need to be addressed through flexible and adaptable government policies. Promoting strong competition across sectors will be crucial in facilitating an environment conducive to strong innovation and technology flows.

Taken together, all these investments emphasize how science and technology can be a force for inclusion, and for lowering inequality. This policy orientation will be critically important in the decades to come, particularly as many mega-trends reshape economies and societies, on top of the adjustments that COVID-19 already demands.

Underpinning all these technology strategies should be strong institutions and good governance, given the double-edged nature of technology, and the need to manage the inevitable disruptions triggered by this coming globalization wave.

SECTION 2.4
SPACE EXPLORATION

The unique view from space has driven great advances in knowledge that spurred innovation and discoveries that have greatly benefited mankind. Space has enabled a global perspective that has been used to address many of the critical issues that are confronting humanity especially anthropogenic environmental and climate change. These issues have been exacerbated by the exponential increase in population that has caused severe stress on our natural resources and the environment. The desire to respond to the needs of a growing population has also led to the use of energy sources and transportation systems that have caused serious pollution of the environment and increases in greenhouse gases that are expected to alter the climate.

To meet these challenges, many countries have launched satellite Earth Observing Systems (EOS) in order to collect much-needed global data that can be used in the study of Earth's climate and environmental system through phenomenological and modeling studies. Satellites have also revolutionized worldwide navigation and telecommunications systems and have greatly improved our mobility and the ability to communicate with each other globally.

Benefits of Space Technology and Exploration

Satellite EOS were launched in recent decades to help address pollution and deforestation.

Among the specific challenges that need to be addressed are the constant basic need for freshwater and food, and the anticipation of and response to natural disasters. Through space technology, it is possible to detect sources of pollution that affect the quality and availability of freshwater for domestic use; we need such information to effectively manage water supply. Satellite data can also be used to monitor extent and yield of agricultural crops. The ability to detect and quantify precipitation and soil moisture has also provided guidance on how to optimize agricultural productivity. Satellite data have also led to accurate forecasts of extreme events that have significantly improved risk management, leading to considerable decline in deaths and property loss. The data have also been useful in the management of flooding, landslides, soil erosion, coral bleaching and harmful algal blooms.

The military applications of satellite data are likewise legion but are usually classified. We can mention here only the publicly-known uses for military strategies, such as the ability to detect ships, aircraft, submarines and possible intrusions into our territorial waters. The use of high-resolution data (<3 meters) also allows for the characterization of enemy troop movements that enables the military to be prepared for impending attacks.

The enormous applications of space technology to the needs of the civilian population cannot be ignored. In industry, technology transfer led to the availability of precision global positioning satellite systems that drastically improved navigation, crystal silicon solar power cells that provide clean energy, long-lasting tires for vehicles, small cameras that are now incorporated in smartphones, ski boots, laptops, computer mouse, wireless headphones, home insulation, thermoelectric de-icing system for aircraft and electrolytic water purification system for swimming pools and domestic needs. In medicine, space technology has led to the development of ultraviolet-blocking sunglasses, computerized axial tomography scans, cochlear implants for hearing aid, ear thermometer and foil blankets. The development of safe pre-packaged foods and freeze-dried technology initially intended for astronauts have also led to the commercialization of these products for general public use. A quantitative summary of the extent to which different sectors of society benefit from space technology is depicted in Figure 2.4_1. It is apparent that among the most frequently cited are overall economy, environmental management, transport and urban planning, research and development, and science and climate monitoring and meteorology (OECD 2019b).

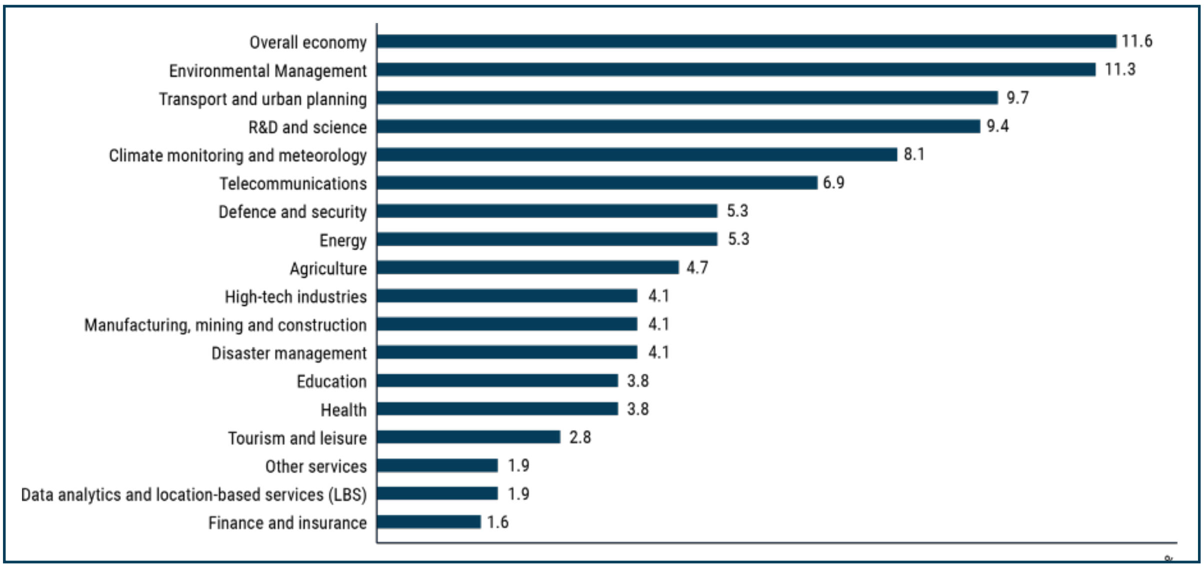
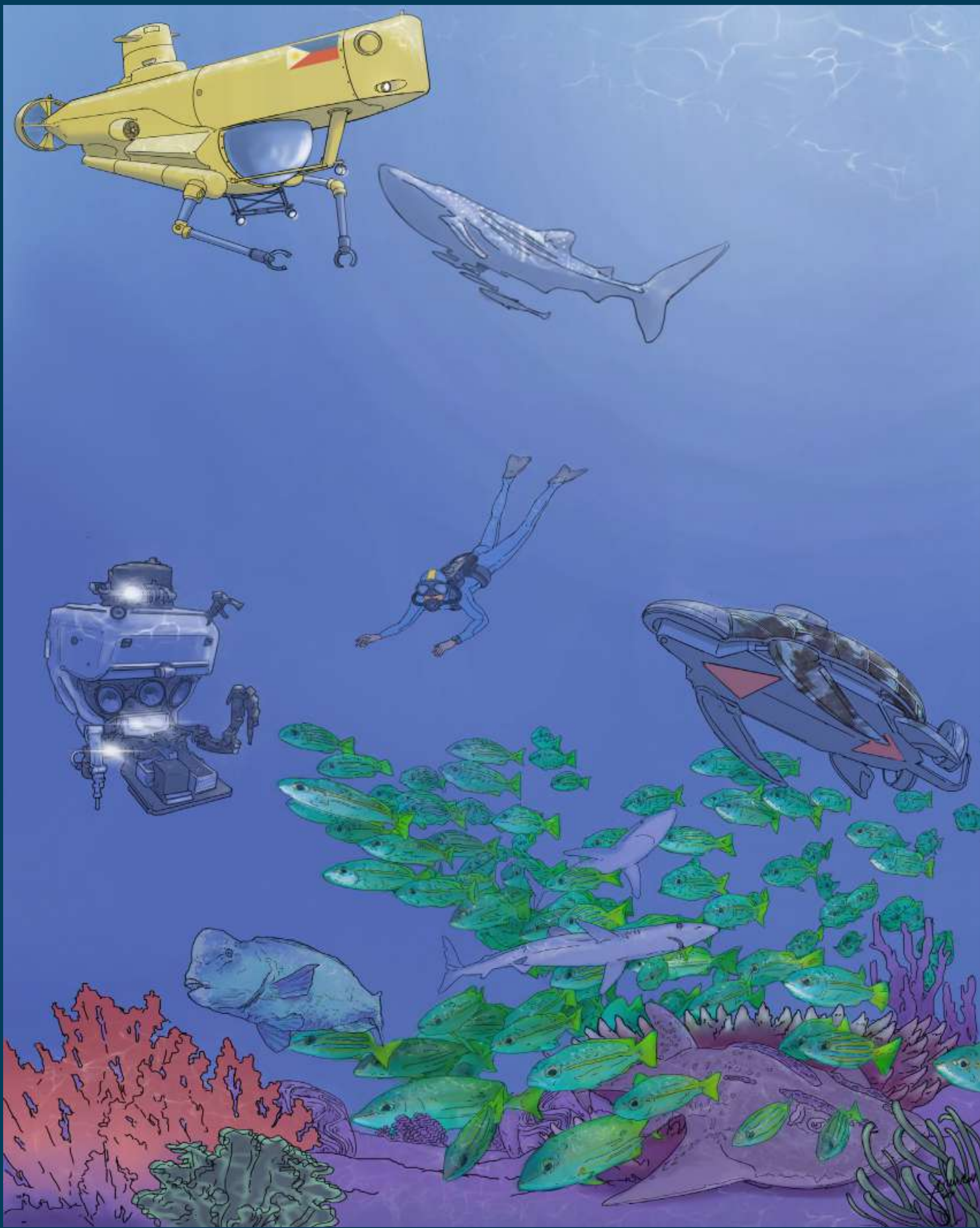


Figure 2.4_1. Selected Sectors that Benefit from Socio-economic Effects Derived from Space Investments.

Source: OECD (2019b)

Notes: The literature covers 77 impact assessments and programme evaluations published between 1972 and 2018.



DIGITAL ARTWORK

Deep Sea Analysis

Primary conceptual idea by Julius Sempio
Art by Jerome Suplemento II

In the not-too-distant future, humans and machines will work together to explore the fullest extent of the Philippines' rich and extensive marine resources. While unmanned research equipment will be invaluable for gathering and processing large volumes of data, there will still be a need for us to visit these unexplored frontiers for ourselves. Here we anticipate the deployment of robot drones that utilize biomimicry to enable them to unobtrusively observe deep-sea flora and fauna. These drones could be set to work over vast areas for extended periods of time, guided by the occasional supervision of trained divers equipped with their own specialized vehicles and tools.

SECTION 3

Setting Sights on the Future: Philippine Goals and Aspirations

SECTION 3.1
THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS AND FUTURE EARTH PHILIPPINES

The United Nations (UN) General Assembly in 2015 decided to adopt 17 Sustainable Development Goals (SDGs) (Figure 3.1_1) intended for global achievement by 2030. These were born from the eight Millennium Development Goals that aimed primarily to "halving the world's extreme poverty rates, stopping the spread of HIV/AIDS and providing universal primary education." The SDG agenda has become a blueprint for galvanizing efforts to meet the needs of the world's less-developed and poorer nations, a "shared vision of humanity and a social contract between the world's leaders and the people."

In the Philippines, being a maritime and archipelagic nation, the SDGs could be considered the bible for implementing development plans from the lowest level to the highest level of government. The indicators of the 17 SDGs are used as achievement benchmarks by the government, non-government organization, and academic institutions. The SDG committees or groups have been established in the legislative and executive branches of the government with the National Economic and Development Authority and the Philippine Statistics Authority acting as the consolidating and coordinating arm.

In 2019, the National Academy of Science and Technology, Philippines through the leadership of National Scientist Lourdes Cruz sought to align with the SDGs by developing the Future Earth Philippines Project—now being proposed to be expanded into the Future Earth Philippines Platform (FEPP). Patterned after the global Future Earth Program, the FEPP is focused on implementing transformative and trans-disciplinary research and networking, as well as in assisting in the achievement of the SDGs towards having a "safe and healthy Philippines" (Figure 3.1_2).

Figure 3.1_1. The 17 United Nations Sustainable Development Goals 2030
Source: Stockholm Resilience Center (2016)

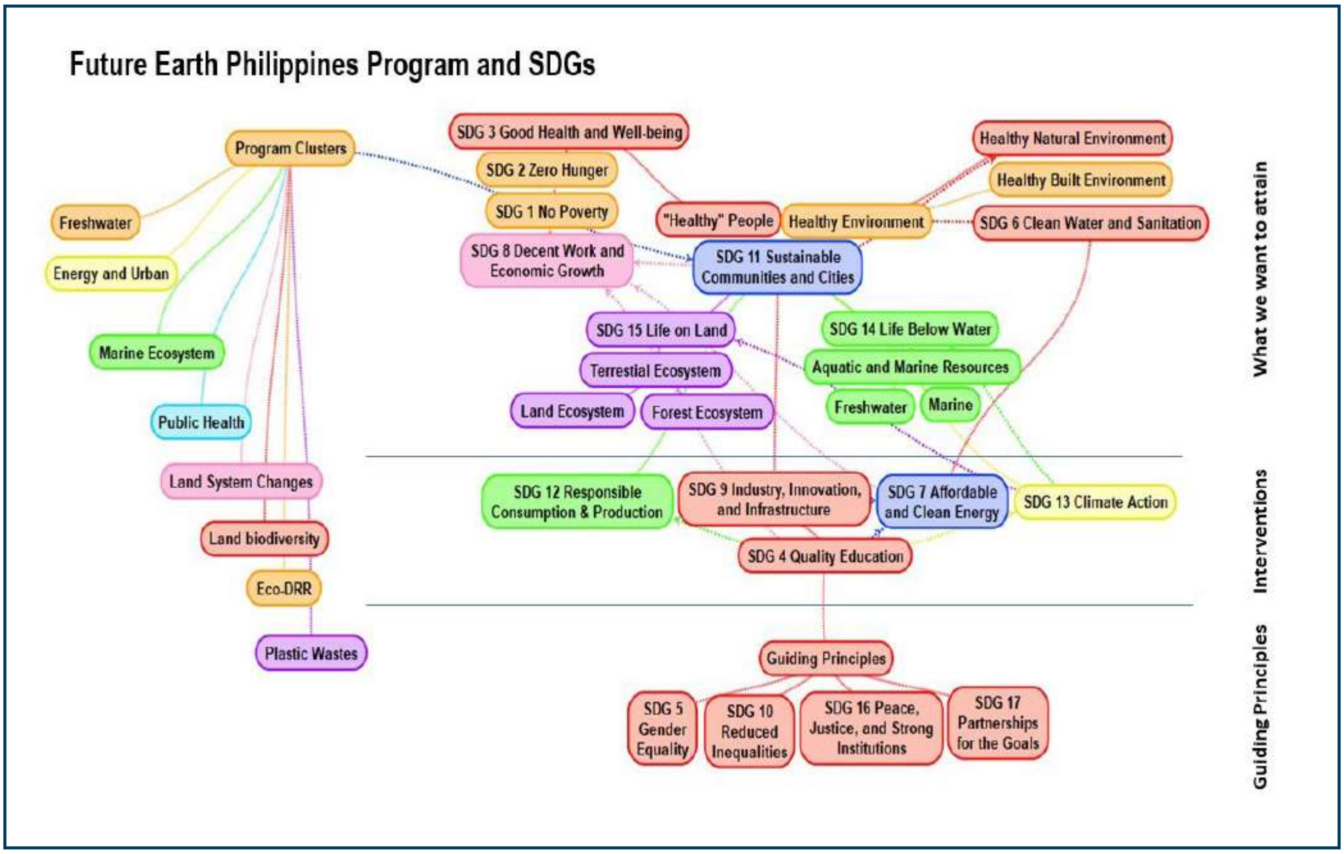


Figure 3.1_2. The Future Earth Philippines Program and the Attainment of SDGs
Source: Azanza et al. (2018) as cited in FEPP (2019)

Three Spheres of the SDGs and Science, Technology, and Innovation support for Sustainability and Productivity

The SDG indicators are inter-related and interactive, as seen in Figure 3.1_1, where the environment/ biosphere is shown as a "bedrock" for sustainability and productivity of the society and its economy. A degraded and non-functioning or malfunctioning environment would not be able to provide the resource base for societal needs. Science, technology, and innovation are vital in the achievement of the SDGs to minimize, if not prevent, proliferation or initiation of approaches and methods that have become non- supportive in our changing world.

Multidisciplinary and trans-disciplinary systems analyses should consider the society's values and preferences. Science- based education on needs and/or demands for old and new products will have to consider the current status and future projections of our environment, society and economy. The following approaches: sustainable consumption and production rates, integration of environmental protection into the countries' developmental plans and circular economy/bio-economy should be major components of adaptive action plans.

The protection of biodiversity, especially in a maritime and archipelagic nation, has been one of the major dogmas for sustained and resilient productivity. More nuanced evaluation of temporally and spatially collected data for global assessments towards the protection of biodiversity and sustainable development is urgently needed; the currently prescribed SDGs are inadequate in protecting biodiversity or are being masked off by development indicators as pointed out by Zeng et al. (2020).

Holistic approaches to environmental sustainability that considers the interconnectedness from the highlands to the oceans, have long been put forward, and need serious consideration particularly in maritime and archipelagic nations such as the Philippines. Proper governance at all levels, with community cooperation are valuable for the SDG Knowledge to Action Programs to succeed, hopefully in the earliest possible time before 2030.

Highlights of COVID-19 Global Impacts on SDGs

The COVID-19 pandemic that started early in 2020 has affected the production and analysis of data for the SDG 2020 Report. Data gaps have reportedly been made serious, making the assessment of progress more difficult. The negative impacts of the pandemic on the different goals made their achievement more difficult in most countries. The following are highlights of the 2020 SDG report and the major influences of the pandemic on each of the 17 SDGs:

Goal No. 1: No Poverty. *The pandemic pushed millions of people to extreme poverty in 63 countries. Natural calamities and social conflicts exacerbated poverty in some of these countries.*

Goal No. 2: Zero Hunger. *Climate effects and social conflicts have been threats to food security with additional negative impacts from the pandemic. An estimated 47 million under five years old are wasting, and millions of the same age are stunted.*

Goal No. 3: Good Health and Well-being. *Less than half of the world is covered by Health Systems. The pandemic has reversed decades of health improvements, and it has interrupted child immunization in 70 countries.*

Goal No. 4: Quality Education. *Progress (for Inclusive and quality education on lifelong learnings), although slow in some countries, has been reversed by the pandemic. Remote learning is made difficult by a lack of infrastructures and appropriate materials.*

Goal No. 5: Gender Equality. *Gender equality has made progress in some countries. During the pandemic lockdowns increased violence against women has been reported. Since more women have been on the frontlines, their household burdens are heightened.*

Goal No. 6: Clean Water and Sanitation. *Before the pandemic, an estimated one billion people lacked access to safe water and basic sanitation facilities. Due to the pandemic, millions more could be displaced by water scarcity by 2030.*

Goal No.7: Affordable and Clean Energy. *Pre-COVID-19 estimates show that one out of four households in developing countries does not have access to electricity; financial support to developing countries for renewable energy source improvements has continued during the pandemic.*

Goal No. 8: Decent Work and Economic Growth. *Before the pre-pandemic, economic growth slowed down, but the worst happened during the pandemic, making unemployment increase further due to stoppage or closure of companies.*

Goal No. 9: Industry, Innovation, and Infrastructure. *Sustainable industrialization and infrastructures almost came to a halt during the pandemic with the deepest decline in aviation; lack of access to the internet negatively affected innovation.*

Goal No. 10: Reducing Inequality. *The Gini Index, which measures the distribution of income across a population, shows that the pandemic further made the Gini index in 38 of 84 countries fall. Thus, making the goal of reducing inequality less achievable by 2030.*

Goal No. 11: Sustainable Cities and Communities. *In 2018, urban population was reduced by 24% globally, making city life more sustainable. However, the pandemic has affected urban cities the most by making urban life less safe.*

Goal No. 12: Responsible Consumption and Production. *Consumption and production rates in many countries are being slowly addressed by the circular economy approach. However, it is now being hampered by the pandemic in some areas where health concerns and food challenges have increased.*

Goal No. 13: Climate Action. *Before 2020, 85 countries have aligned with the Sendai Climate Change framework. A drop of about 6% in greenhouse emission has been recorded during the pandemic, but it is still short of the 7.6% reduction to lessen global warming by 1.5 degrees centigrade.*

Goal No. 14: Life Below Water. *Lack of data from some areas and continued degradation of coastal and marine habitats before and during the pandemic have been observed, but with the recuperation of some resources during the pandemic, plastic pollution remains to be a threat to life below water.*

Goal No. 15: Life on Land. *In 2020, forest degradation has been estimated to reach 2 billion hectares worldwide, affecting about 3.2 billion people. Biodiversity conservation efforts have intensified.*

Goal No.16: Peace and Justice Strong Institutions. *International cooperation for peaceful and safe societies has failed in some areas where there are still internal and external conflicts.*

Goal No. 17: Partnerships to Achieve the Goals. *That "no one should be left behind" through global partnership made possible, primarily through the Overseas Development Assistance remained unchanged until 2019 but this scheme could fall because of the pandemic since many of the donor countries were likewise affected.*

SECTION 3.2
DEVELOPMENT PLANS: SOCIOPOLITICAL ISSUES, FILIPINO ASPIRATIONS, AND SCIENCE, TECHNOLOGY, AND INNOVATION

The social and political dimensions relevant to the pursuit of inclusive development in a maritime and archipelagic Philippines are herein identified to ensure inclusive growth and competitiveness that will benefit all Filipinos, especially those in marginalized sectors.

The Philippine population, though still generally younger, will have started to age by 2050, with 16% above 60 years old (Population Pyramid 2020). By contrast, those who are born in 2020 will be young professionals by then. Those younger than 30 years old will constitute 43.5% of the population. At the same time, two-thirds of Filipinos (65.6%) will be residing in urban areas in 2050, up from less than half of the population (48.6%) in 2010 (Navarro 2014). Such demographic transitions, along with patterns of economic growth and urbanization, are all linked to development. However, to make this development inclusive—a perennial challenge for the Philippine economy—social and political considerations need to be taken seriously.

We also need to understand these issues in relation to our collective aspirations as a people, for which science, technology, and innovation (STI) will play a fundamental role in both charting and navigating our way towards their attainment. In the latter part of this section, we endeavor to lay out the historical precedents and future functions of STI in the context of nation building.

Sociopolitical Issues

The following issues will be explained in detail: democratic challenges, youth welfare, Bangsamoro concerns, and China’s persistent aggression. Although not exhaustive, these have been identified given their long-term impact on the ability of the Philippines to progress sustainably and equitably. Indeed, by the time the Philippine population breaches 144 million in 2050, these and other issues will continue to impact the country’s sociopolitics as well as its economy. They demand immediate attention from social scientists and policy makers.

While these needs are already current, their consequences on Filipinos are predictably complex and long-term. Addressing them early on will ensure that economic gains are to be equitably shared. Each of these issues entails very specific needs, which will be explained in detail.

Democratic challenges. Although the Philippines regained its democracy in 1986, much remains to be desired when it comes to the quality of democratic participation among Filipinos. It is true that democratic institutions and processes are in place. Institutions such as the different branches of the government have been generally stable and processes such as the elections honored.

However, this democracy is defective. Despite the fact that the Philippines might officially be Southeast Asia's oldest democracy, clientelism in politics maintains the inequalities that have defined Philippine society for centuries (Teehankee and Calimbahin 2020). At the same time, scholars have brought up several concerns in recent years about the eroding quality of democracy in the Philippines. The popular support for strongman rule, for example, underpins the popularity of what Thompson (2016) considers "illiberal reforms" in the name of law and order.

Indeed, campaigns against criminality, including the war on drugs and the potential reinstatement of the death penalty, are widely supported, as they relate to people's fears and anxieties about security in their own communities (Curato 2016). Within a context of impunity, these sentiments will linger in the years to come, engendering distrust of state agencies mandated to administer peace and order. At the same time, inequality sustains these sentiments, as marginalized sectors feel that they cannot rely on the justice system to decide in their favor. Reinforcing these sentiments are anti-deliberative discourses. For one, statements made by public officials have de-legitimized the voices of critical citizens (Rüland 2020). Also, certain policies may be inimical to democratic participation.

Civil society actors have been alerted to the threat of the Anti-Terror Law in silencing dissent among themselves. The work of "networks of disinformation" that shape public opinion on social media can be added to the list (Cabañes and Cornelio 2017; Ong and Cabañes 2018). Indeed, disinformation in the form of "corrosive falsehoods", "moral denigration", and "unjustified inclusion" has been shown to arrest the potential of democratic conversations about pressing issues (McKay and Tenove 2020).

Furthermore, the call for greater democratic participation is intensified by the transformation of the youth, who are increasingly alienated from politics, as they are far more invested in personal economic advancement (Cornelio 2020a, b).

Taken together, these issues pose challenges for the future of democratic participation among Filipinos, with respect to the values it demands. These values include accountability, civil and political freedom, political and economic equality, and deliberative capacity. The latter, in particular, recognizes the need for citizens to engage with differing perspectives in the hope of coming up with conscious collective decisions (Curato 2015).

Youth Welfare. The second need concerns the future of the youth. The Philippines will continue to have a young population by 2050, even as society begins to show signs of ageing. Their overall welfare thus deserves particular attention.

One area that needs intervention is political representation that can effectively uphold their interests. This is much needed, given the inability of Sangguniang Kabataan (SK) to attract their attention. In recent elections, the SK failed to secure enough candidates for all open positions, and there are no signs that this will improve in the future. While SK proves to be a useful avenue for fostering political participation among the youth, this is not the case in many communities around the Philippines, where they are socialized into corruption by adult politicians (Ponce et al. 2013). Scholars in youth studies are of the collective opinion that the future of political participation rests on young people who are convinced that they can make a positive difference in society (Schwartz 2010).

The state of education is another area that needs attention to ensure that youth welfare is addressed. In the past decade, the government's *Pantawid Pamilyang Pilipino Program*, a conditional cash transfer mechanism, has increased school enrollment (Catubig and Villano 2017). K-12 education was also implemented with a view to preparing young people to become more globally competitive as a workforce.

The long-term impact of these policies on national development has yet to be seen (Adarlo and Jackson 2017). One critical area is not only sustaining retention, but ensuring the quality of education that fosters critical thinking and scientific consciousness.

At the same time, the quality of tertiary education is uneven across the country. This is worth investigating, given the subsidies accorded to state universities and colleges to foster universal education. Some scholars argue that this is a strategic investment for the country (Lim et al. 2018).

Another area is the capacity of the job market to absorb this highly-educated workforce in due course. Many advanced countries will continue to rely on foreign labor, certainly an opportunity for highly educated Filipinos (Tan 2019).

Finally, the physical well-being of the youth will remain a formidable challenge in the years to come. Malnutrition, stunting, and mortality are connected to the problem of hunger that affects the most impoverished families (Salvacion 2017). Securing their nutrition is directly tied to national development interests. No less than economist Cielito Habito (2020) claims that hunger is "a major factor behind our underdevelopment and historical lack of economic dynamism relative to our regional neighbors." After the incidence of hunger among households had fallen gradually from 19.1% in

2010 to 9.3% in 2019, it shot up again to 20.9% by mid-2020, as livelihoods were severely disrupted by the government's non-selective reactions to the COVID-19 pandemic (SWS 2020b).

Bangsamoro concerns. The welfare of the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) is the third socio-political need that will remain imperative in the years to come.

In 2019, BARMM officially replaced the Autonomous Region in Muslim Mindanao and adopted a parliamentary system with more powers devolved from the national government. With an overhauled government, the region aspires to progress economically and politically. While it is a culmination of a long journey for a collective identity and lasting peace, the Bangsamoro struggle is far from over (Caballero-Anthony 2007).

The region is the poorest in the country. This is true even after it registered high economic growth rates in recent years. In 2018, its Gross Regional Domestic Product grew by 7.2%, banking heavily on agriculture, hunting, forestry, and fishing (BARMM Government 2019a). By the end of 2019, many reforms were introduced, including the approval of the Bangsamoro Transition Plan, the decommissioning of Moro Islamic Liberation Front combatants, and wage adjustments (BARMM Government 2019b). Despite these laudable developments, formidable challenges remain for Bangsamoro, as it "has long been the most impoverished region in the Philippines, despite its high economic potential by virtue of its rich natural resources" (Taniguchi 2020).

Based on the Family Income and Expenditure Survey in 2018, the average annual family income in the region is PhP 161,000, the lowest in the entire country (PSA 2018d). Poverty and subsistence incidence rates reveal the same pattern. 61.8% of the population in the region are poor (PSA 2020c). The biggest proportion are in the provinces of Sulu (82.5%) and Basilan (73.5%). In terms of subsistence incidence, the region has the highest in the country, at 23.3%. The most affected provinces are Basilan (34.1%) and Sulu (31.5%). Worsening the poverty situation in Mindanao is the constant experience with conflict. Conflict turns poverty into a chronic problem, as it destroys livelihood, shelter, and communities (Malapit et al. 2003).

The Marawi Siege may have ended in 2017, but its repercussions are long-term. Delays in rehabilitation have made it impossible for the city's original inhabitants to return and reclaim their property. Many continue to be disenfranchised from the reconstruction process, thus engendering more resentment. In conflict and peace-building studies, the participation of locals in the reconstruction process is key in fostering ownership and preventing the resurgence of violent extremism (Schwartz 2010). This much is true in the experience of Moro youth (Cornelio and Calamba 2019). The persistence of conflict and violent extremism remains due to the remnants of Islamic State of Iraq and Syria Philippines in the region. Banlaoi (2019) warns that they can "undermine the implementation of the BOL [Bangsamoro Organic Law, RA 11054], sow terror in Mindanao, and ensure that peace remains elusive."

China's persistent aggression. Finally, the rise of China as a superpower raises important social and political concerns for Filipinos in the future. As it is, China has already asserted its military might in the West Philippine Sea, which the Philippines has been unable to protect effectively.

To compensate for this inadequacy, the Philippines previously sought the intervention of the Association of Southeast Asian Nations in addressing regional security matters. Under the current administration, the government implemented a shift in foreign policy to appease China, hoping to generate investments in the Philippines from China's Belt and Road Initiative (de Castro 2020).

But beyond the military, the aggression of China spells many other social and political challenges for the Philippines, and Southeast Asia as a whole. The first is the historical basis of the claim over the South China Sea, a name that should be contested by the entire region. A cue could be taken from the decision of the Arbitral Tribunal on the Law of the Sea that China's "9-dash line" is spurious. For Malik (2013), "China's claim to the Spratly's based on history runs aground on the fact that the regions past empires did not exercise sovereignty. In pre-modern Asia, empires were characterized by undefined, unprotected, and often-changing frontiers." The claim of a "9-dash-line" is a narrative being perpetuated by the Chinese state among its own citizens, since it is not accepted by any other country in the world.

A serious area of concern is the influx of new immigrants from mainland China to the Philippines. This is a trend that is taking place all over the region, as Chinese investments and business interests grow. The work of the Overseas Chinese Affairs Bureau must be carefully monitored, as new immigrants have engendered tensions not only with local Filipinos but even with Chinese-Filipinos. For See and See (2019), Chinese-Filipinos "have acculturated and integrated into the mainstream of their respective countries. To treat these people as huiqiao, or consider them as 'assets' or 'secret weapons' of China, risks not only stoking their resentment at the forced co-optation but may also revive Cold War-era anxieties about their loyalties and allegiances."

Filipino Aspirations

The above sociopolitical realities will influence future development initiatives. It is important that we can relate these factors to our aspirations as we chart solid paths towards the wellbeing of an archipelagic and maritime nation.

The vision for science and technology (S&T), its role in national development, and the strategic agenda for each discipline, industry, and sectors within STI is situated within the context of a national vision for the country. Societal goals and visions are important guiding principles for the direction and objectives of any development agenda. For the country, these societal ambitions are deeply held values and ambitions, reflected in policy, and in fact, enshrined in the constitution. This section begins with the former, the current societal goals as expressed individual ambitions of Filipinos gathered through a deeply consultative process. It is followed by a review of the legal statutes that, though decades old, still reflect the findings of the AmBisyon Natin 2040 initiative.

In 2015, the NEDA conducted a visioning exercise, a rigorous and methodical national public consultation with Filipino citizens to inform the formulation of a collective long-term vision for the country. It was not a vision only by leaders and elites in the society; it represented the Filipino people's aspirations, for their country, for their families, and for their children's futures. The resulting vision statement and document is AmBisyon Natin 2040, a set of goals for the year 2040 that would ideally guide each political administration's agenda between 2016 and 2040.

As a people, the life that Filipinos want to have is stable, comfortable, and secure. They are guided by strongly rooted values that place family, friends, and community at the center. People are concerned about hunger, health, education; they also aspire to provide for their children and their parents and have a life free of worry and hardship. The vision statement at the level of people is:

In 2040, we will all enjoy a stable and comfortable lifestyle, secure in the knowledge that we have enough for our daily needs and unexpected expenses, that we can plan and prepare for our own and our children's future. Our family lives together in a place of our own, and we have the freedom to go where we desire, protected, and enabled by a clean, efficient, and fair government.

What does this mean for the country? As a society, Filipinos' individual ambitions for their lives add up to a country vision that provides equal opportunities for all, allows prosperity that includes the poor and the vulnerable, and brings the marginalized into the economic development of the country. It is articulated in the Philippines' development ambition as:

> *By 2040, the Philippines shall be a prosperous, predominantly middle-class society where no one is poor. Our peoples will enjoy long and healthy lives, are smart and innovative, and will live in a high trust society.*

These same societal aspirations and the values that guide them are enshrined in the 1987 Constitution. Articles II and III stress the central importance of equality of opportunities and improvement in the lives of the underprivileged. These have underpinned the goals and priorities of all Philippine Development Plans (PDPs) over the years. In particular, the priorities of national policies must include providing:

(1) a more equitable distribution of opportunities, income, and wealth
(2) a sustained increase in the amount of goods and services produced by the nation for the benefit of the people
(3) an expanding productivity as the key to raising the quality of life for all, especially the underprivileged

Consistent attention is placed on the welfare of the poor. In 1997, RA 8425 or the Social Reform and Poverty Alleviation Act was passed, and programs were implemented through the National Anti-Poverty Commission. The law sought to ensure that marginalized sectors participate in government decision-making and stipulates that every poor Filipino family shall be empowered to meet its basic needs such as:

- health, food and nutrition
- water and environmental sanitation
- income security
- shelter and decent housing
- peace and order
- education and functional literacy
- participation in governance
- family care
- psycho-social integrity

Filipinos have deeply rooted concerns for social and economic inclusion, for building a country where nobody is poor, nobody is hungry, and nobody is left behind. These remain relevant goals, more than 30 years after the 1987 Constitution was adopted. Inequalities in income, political participation, protection from shocks, opportunity for upward mobility, access to justice, and inclusion in civic life persist across social class, geographic boundaries, and other social categories. One way to illustrate the depth of this inequality is through income inequality, commonly measured through the Gini index. The Philippine Gini coefficient—high by Asian standards—had not reduced dramatically from 1997 to 2018 (Figure 3.2_1).

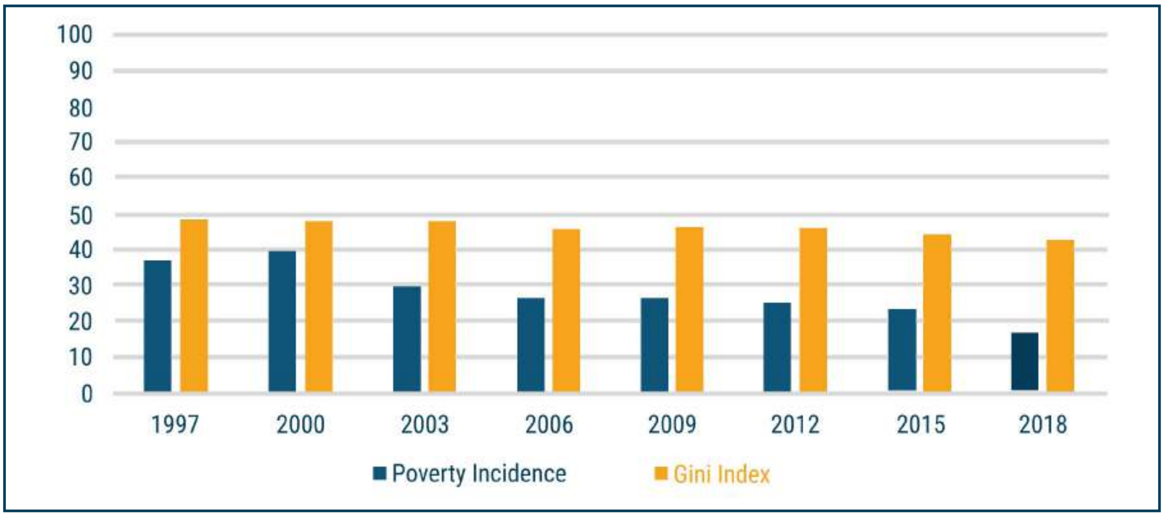


Figure 3.2_1. Philippines' Poverty Incidence and the Gini Index, 1997 to 2018.
Source: PSA (2015b, 2015c, 2019d, 2020c)

People's aspirations, desires, and concerns are stable. These will change only when real and inclusive economic and social progress is achieved. Filipinos' core values inform what they believe should be the priorities of a nation and its government. Even as governments change, as the country experiences deep shocks and windfalls, and even as the global context may change, that which the Filipino people hold dear and want to protect, will not. Thus, even if the work that informed AmBisyon Natin 2040 is now five years old and the Philippine constitution now over 30 years old, and even as the country is shaken by COVID-19 and natural hazards (typhoons, floods, earthquakes), the vision highly likely remains a relevant guidepost for PAGTANAW 2050.

Development Plans and Achievements Through the Years

This section will cover only the developments from the Cory Aquino administration to the present.

Since the beginning of democratic governance in 1987, government development plans focus on improving living standards, reducing poverty, achieving equitable growth, and making development environmentally sustainable development.

The 1970s and early 1980s were characterized by deep global recession, sharp falls in world prices of the country's traditional exports, and internal political turmoil punctuated by the assassination of Benigno Aquino, Jr. in 1983. Following the economic crisis of 1984–1985 and the Marcos regime's loss of political credibility, a new government was voted in February 1986, with Corazon Aquino as President.

The Corazon Aquino government's development program stressed poverty alleviation, generation of more productive employment opportunities, and promotion of equity and social justice. The strategy adopted to achieve these goals took a market-based development approach, calling for the removal of policy biases against agriculture and the rural sector, and thus, improving profitability of labor-intensive and agriculture-based non-traditional exports (Balisacan 2003). It embraced an employment-oriented, rural-based development strategy, with the Comprehensive Agrarian Reform Program, as its centerpiece. However, although the administration's central theme for poverty alleviation was rural development, it failed to address the single most important constraint to sustained rural development, namely the poor state of rural infrastructure, particularly transport, electricity, and water, including irrigation (Balisacan 2003).

Fidel V. Ramos' administration's (1992–1998) key strategy was people empowerment and international competitiveness through the development of a skilled workforce, investments in human capital, and upgrades of technology—most notably the Philippines' connection to the internet on March 29, 1994 (DICT 2015). The plan was to pursue industrialization and rapid growth in average incomes to achieve human development. People empowerment implied reliance on markets, entrepreneurship, innovations, and growth-facilitating institutions. There was a Social Reform Agenda (SRA) for achieving human development targets, a pioneering effort to push the various government sectors toward securing the minimum basic needs of families as a first priority. A package of government interventions was organized around "flagship programs" for the country's 20 "poorest" provinces. But the SRA failed due to policy implementation problems (Collas-Monsod and Monsod 1999, cited in Balisacan 2003).

The Ramos administration plans included accelerating economic growth by building the international competitiveness of domestic industries, reforming regulation in services and industry in commercial banking, transportation, and telecommunications, and investing in basic infrastructure. Large and forward-looking investments in power generation and transmission, transport, and communication were also made. Overall, economic growth accelerated, and welfare of the poor responded respectably to this growth (Balisacan 2003). However, the Asian economic crisis of 1997–1998, combined with a severe El Niño, disrupted the momentum.

The brief period of the Estrada administration (1998–2001) had a pro-poor and "growth with equity" agenda that recognized broad-based sustainable rural development as a path to reduce poverty. The plan envisioned an aggressive delivery of basic social development services, removal of policy and regulatory distortions inhibiting resource allocation efficiency and equitable outcomes, sustained development of rural infrastructure, improvement in governance, and macroeconomic stability. A limited run of its flagship program *Lingap Para sa Mahihirap* (Looking after the Poor) led to poverty outcomes inferior to those of other schemes tried in the recent past (Balisacan 2003).

The Macapagal-Arroyo administration's (2001–2010) ascension to power following the ouster of President Estrada gave birth to another program for direct poverty alleviation, called KALAHI *(Kapit-Bisig Laban sa Kahirapan or Joining Hands against Poverty)*. This program engaged in asset reform, provision of human development services, creation of employment and livelihood opportunities, participation of so-called basic sectors in governance, and social protection and security against violence.

Between 2000 and 2010, new jobs were created by the expansion of call centers and business process outsourcing, information and communications technology, tourism, and mass housing. creating new jobs, especially in urban areas. The implementation of the Agriculture and Fisheries Modernization Act (RA 8435 and 9281) to generate one million jobs in agriculture and related industries was planned, but funding far fell short of expectations. Self-employment and entrepreneurship were encouraged, with special emphasis on micro, small, and medium-scale industries development. Deregulating industries and privatizing government continued.

One new attribute of the plan was its emphasis on S&T and green production technologies. The plan was to develop high value-added products — products which generate the most income for their Filipino producers — through investments in S&T, for which a culture of research and development would be fostered. There were efforts to step up the development of microenterprises (very small family- and community-based businesses) and small and medium enterprises, and promote clean production technologies to minimize the environmental impact of industrial growth.

Arroyo's scorecard showed that it failed to address key social and economic challenges relating to persistent poverty and inequality. There were improvements on the policy front, but many governance challenges and social inequities largely left unaddressed (Rood 2010). It was further noted that based on the World Bank indicators, chronic problems such as corruption had worsened, which was deemed as a "key reason behind the Philippines' anemic progress in economic and human development." However, Arroyo's smart 2003 "roll-on roll-off" maritime initiative, which brought down the shipping cost among the Philippine islands by 30 to 40%, was treated as a historic policy success. The lack of commitment to agricultural development reflected the broader underdevelopment of the rural sector. This contributed to a pattern of growth that left behind millions of Filipinos and failed to make major inroads in poverty reduction.

The Benigno S. Aquino III Administration's (2010–2016) development plan centered on inclusive growth, defined as "growth that leaves no one behind," where poverty reduction was seen in "multiple dimensions" (NEDA 2011) and massive creation of quality employment as the desired outcome. Strengthening the macroeconomic fundamentals was key to fostering consumer and business confidence in the economy, resulting in sustained high economic growth averaging 6.2% throughout the term as well as a substantial reduction of poverty incidence from 39.4% in 2000 to 16.7% in 2018. Investment, both public and private, in the production sectors (i.e., agriculture, industry, and services) was regarded as a critical determinant of the economy's growth potential and its ability to create quality jobs. This administration highlighted the role of science and technology policy in influencing private investment in research and development to raise productivity and expand the range of products and services produced in the economy. The state of the country's infrastructure (roads, ports, airports, telecommunications, transportation, etc.) and the availability of a healthy, highly trainable, and skilled labor force are important factors for a more efficient business climate. Likewise, the plan mentioned the important contributions of good governance, the high quality of natural environment, and national security to the economy's productive potential.

The Philippine Development Plans (PDPs) are plans; they reflect what administrations intend to do. Outcomes of well-laid plans can only be realized when accompanied by strong performance in implementation. The above review of PDPs suggests a disconnect between development planning and actual outcomes that has to largely do with limitations in governance.

Over the decades, the PDPs have been broadly responsive to changing economic conditions and realities, including global trade and finance.

However, the connection of development plans with budget decisions and policy choices has been quite weak. Little attention was paid to the governance that underlies effective implementation and success in the long haul. The challenge, therefore, is to build governance institutions that ensure the attainment of our aspirations.

The AmBisyon Natin 2040 was used to set development goals that would guide each political administration over the next 25 years, starting with the Presidential term of Duterte (NEDA 2016). These goals are defined along four areas:

(a) Building a predominantly middle-class society
(b) Promoting a long and healthy life
(c) Becoming smarter and more innovative
(d) Building a high-trust society
(e) Disaster Risk Reduction and Climate Change Adaptation (DRR CCA)

In pursuing these goals, the Duterte administration's PDP 2017-2022 (NEDA 2017) strategic policies, programs, and projects to achieve the following medium-term outcomes:

(a) The Philippines will be an upper middle-income country by 2022.
(b) Growth will be more inclusive as manifested by a lower poverty incidence in rural areas.
(c) The Philippines will have a high level of human development by 2022.
(d) The unemployment rate will decline from 5.5% to 3.5% in 2022.
(e) There will be greater trust in government and society.
(f) Individuals and communities will be more resilient.
(g) Filipinos will have a greater drive for innovation.

Many of these medium-term targets and the long-term aspirations envisioned in AmBisyon Natin 2040, are endangered by the massive disruptions caused by the COVID-19 pandemic. In particular, the health crisis and the sharp economic contraction in 2020 have reversed gains in job creation and poverty reduction in recent years. That could mean some lost years of socioeconomic development. The challenge ahead is taking decisive actions to get the economy to recover quickly and use the crisis as an opportunity for policy and governance reforms to strengthen the health care system and make the economy more resilient to shocks and risks.

Science, Technology, and Innovation Towards Inclusive Prosperity and A Globally Competitive Knowledge Economy

Filipinos' top concerns are the fundamental problems of poverty, hunger, equal opportunity, and financial security. As such, the strategic role of STI to contribute to AmBisyon Natin 2040 is an enabling tool toward attaining the country's aspiration to be a predominantly middle-class society free of poverty.

Based on the national survey conducted for AmBisyon Natin 2040, most Filipinos believe that the most important condition the country should strive for by 2040 is that no one is poor (29%), no one is hungry (25.7%), and all Filipinos should have a chance to get a job that adequately provides for their needs (18.2%).

The prioritization for the country's STI agenda can directly address some of the critical constraints individuals experience in their daily lives. For example, based on the qualitative group discussions that informed AmBisyon Natin 2040, Filipinos aspire for their country affordable high-quality health care and education, western-level development that respects Asian values, an urbanized and modern and technologically advanced country, and widely available welfare support. They want a just and fair society where opportunities are available to all and progress is felt in all areas of the country. STI can point to pathways toward improving public health and medicine for the specific needs of communities or fostering innovation in green growth and improving air pollution, for instance.

Instability is a part of Filipino life, and shocks to income and personal safety require resiliency at the level of people, community, and environment. Natural calamities, poor management of densely populated areas, and armed conflicts are some of the sources of these shocks. Hazards are understood as products of environmental degradation and pollution. As such, Filipinos place much importance on conservation, environmental protection, and working toward building sustainable communities that are resilient against natural hazards. Those living in urban centers are concerned about how economically oppressive it can be and how the emphasis should be on building "livable cities." These are all aligned with the goals articulated in [Section 4.1] on green growth, marine conservation, blue economy, and other work meant to contribute to the climate agenda.

Within this context where Filipinos' ambitions and constraints are clearly articulated, how can STI best serve the demands and the needs of the people?

STI can play a critical role in attaining these development goals by (UN ECOSOC 2013):

- fostering access to knowledge
- increasing productivity
- industrialization
- economic growth
- creating decent jobs
- promoting health and access to essential drugs
- achieving food security through sustainable
- equitable agricultural systems
- raising production and incomes
- especially of smallholder farms
- promoting renewable energy technologies to respond to the dual challenge of reducing poverty while mitigating climate change

STI was first explicitly mentioned in the Macapagal-Arroyo PDP (NEDA 2004), with reference to green technologies and more environmentally sustainable issues. The Aquino PDP (NEDA 2010) created space for private sector investments in STI for job creation. The current administration is highly supportive of STI and its role in attaining the Filipino aspirations.

Among the various goals and values reflected by the citizenry, two particularly stand out as having a strong link to STI. The first is **inclusive prosperity**, namely equal access to the most basic services that will allow people to work toward their own betterment, such as knowledge or education, health, and a long life, and the ability to compete for opportunities with others, on equal footing, regardless of their social and economic backgrounds. Extreme economic and political concentration in the country is deeply felt and understood by many as a constraint not only on individuals but also on the Philippines' overall national development. Breaking the trend toward further concentration, and pursuing equality in opportunity, will require a strong contribution from STI to ensure that the opportunities it opens up do not exclude those who have not had a good education or do not have access to technologies.

Innovations can easily lead to more vast gaps between the haves and the have-nots. This has been the pattern for digital divides, availability of quality STEM education, or accessibility of cutting-edge medical care. How can innovations be more inclusive? How can these be designed or incentivized to specifically close gaps, allow the have nots to catch up, and for new technologies to diffuse to all?

The second is the national goal to be a **globally competitive knowledge economy**. What will the country need to move from being a service economy to a knowledge economy? We will require investments in building intellectual capital, in creating an environment where Filipino scientists, engineers, and others have the tools, resources, and capacity to generate knowledge and trade in it. STI will need to be strongly linked to other knowledge economies, so that the country can evolve from trading in goods and labor to generating productivity from intellectual property and innovation. More importantly, the country will need to develop a corps of skilled workers with high-quality STI-related education.

Whether competitiveness in the knowledge economies is something the Philippines is prepared for at this point is, in many ways, influenced by the global context. Development of STI to build a knowledge economy is necessary, even just to catch up and not be left behind. Where it would best serve the demands of Filipinos is in its focus on the subjects that people need and care about, for instance, focus on building an STI ecosystem that is specifically inclusive for those from poor families, or have a focus on biodiversity conservation for the green and blue economies to protect the country and its people from natural hazards. Thus, where PAGTANAW 2050 can meet AmBisyon Natin 2040 is in its focus areas and how well these serve the people's aspirations as a maritime and archipelagic nation.

DIGITAL ARTWORK

Cityscape

Primary conceptual idea by Jerome Suplemento II
Art by Jerome Suplemento II

In the face of the world's burgeoning population, urban planning has become all but essential for ensuring the optimal efficiency and livability of the world's crowded cities. Current research has underscored the necessity of green areas such as dedicated parks and pocket forests to the sustainability of these cityscapes even while accounting for inevitable hazards such as typhoons and earthquakes. This artwork visualizes a future Philippine city that is planned and built with these hazards in mind, while integrating trees, shrubs, and other flora into the urban landscape—so much so that some structures are built with the specific goal of sustaining plant life as well as for providing shelter for their human occupants. The Philippines' endemic flora, from Rafflesia flowers to anahaw leaves, are also a rich source of inspiration for engineers, designers, architects, and urban planners for new building materials and livable designs.

SECTION 4

Facets of Philippine Science, Technology, and Innovation

SECTION 4.1
THE BLUE ECONOMY

The oceans are the planet's largest life-support system. They cover over 70% of the earth's surface, providing various ecosystem services; nurturing biodiversity; storing carbon; and stabilizing climate. They directly support human well-being through food, minerals, industrial materials, energy resources, and cultural and recreational services. Several national and international strategies (e.g., Portugal and EU) have espoused "Ocean strategies" and "Blue Economy" approaches to ensure the long-term sustainability of both ocean ecosystems and the economy. In July 2012, country representatives from East Asian Seas signed the "Changwon Declaration". They agreed to adopt the Blue Economy, defined as "a practical ocean-based economic model using green infrastructure and technologies, innovative financing mechanism and proactive institutional arrangements for meeting the twin goals of protecting our oceans and coasts and enhancing its potential contribution to sustainable development including improving human well-being and reducing environmental risks and ecological scarcities" (PEMSEA 2012).

The "blue economy" approach is imperative in the Philippines, an archipelagic country with territorial seas that are twice the size of its total land area (see Section 1.6, Geographic Features and Natural Endowments). The coastal areas, where the majority of Filipinos live, are the centers of many economic activities. The natural capital in the territorial seas and the exclusive economic zone can contribute significantly to providing livelihood, food security, materials, and vast opportunities for a sustainable and prosperous blue economy (Azanza et al. 2017). The Bureau of Fisheries and Aquatic Resources reported that in 2019, Philippine Fisheries production consisted of 47.1% wild per capture and 52.9% aquaculture, mostly from municipal waters (Tabios B 2019). Climate change impacts and other hazards on the coasts that threaten the marine environment are predicted to worsen in the coming years (see Section 4.10, Environment and Climate Change), and thus should be part of adaptive development plans particularly with regard to fisheries and aquaculture in the blue economy.

In the immediate future, the country should be able to prepare and implement a comprehensive action plan for a National Coast and Ocean Strategy, making the present Foresight for a science, technology, and innovation (STI)-based development of its blue economy a starting or shifting point. This will allow the Philippines to anticipate and make important changes to its national political, economic, and social spheres, as well as to its stance vis-à-vis Asian neighbors and the rest of the world. The National Academy of Science and Technology, Philippines (NAST PHL), in preparing this Foresight has agreed to refer to the country as a " Prosperous, Archipelagic, Maritime Nation." (Section 1.1, STI Foresight Framework) in order to make the sea/ocean a unifying and driving force for our national aspirations in the years to come.

Trends in Blue Economy and Impacts

As stated in Section 2.2, the Organization for Economic Cooperation and Development (2016) estimates that in 2010, ocean-based industries contributed about USD 1.5 trillion or 2.5 % of the gross value added with approximately 31 million jobs coming from the ocean economy in the same year. Strong growth is expected such that, by 2030, 40 million full-time equivalent jobs will be generated annually—mostly coming from marine aquaculture, offshore wind turbines, fish processing, and shipbuilding and repair. There is immense interest in ocean-based industries' growing potential among public and private partnerships at various regional scales. The related investment needs highlighted by governments across East Asia are as follows:

- Coastal transport
- Ecotourism/sustainable tourism
- Energy
- Enterprise and livelihood development
- Fisheries and food security
- Habitat protection
- Restoration and management
- ICM development and implementation
- Natural and man-made hazard prevention and management
- Pollution reduction and waste management
- Water use and supply management

Filipinos are already culturally and practically entwined with our oceans. About 60 million people currently live in low-elevation coastal zones, and all of the big cities can be found right beside the coast. Several blue industries already contribute significantly to the gross domestic product (GDP)(Table 4.1_1):

(1) Tourism, resorts, and coastal development
(2) Fisheries and aquaculture
(3) Coastal manufacturing
(4) Ports, shipping, and marine transport
(5) Ocean energy
(6) Seabed mining for oil, gas, and minerals
(7) Marine biotechnology and medicine
(8) Marine technology and environmental services

Table 4.1_1. Current Blue Industries in the Philippines

Industry	Known % contribution to GDP	Current state and workforce	Potential development/Recommendations
Tourism	25	5.71 million workers	Biodiversity-centric tourism
Fisheries and Aquaculture	20	1.6 million workers	Integrated open water, multi-trophic aquaculture
Manufacturing	19	300 thousand workers	Infrastructure development, projected sea-level rise and modeled storm surge
Ports and Shipping	12	229,000 seamen Overseas Filipino Workers and 8,000 local ports and shipping	Hanjin in Subic, Philippines considered as the fifth world's largest shipbuilder
Ocean Energy	11	Coal-fired thermal plants now account for 43% of the national energy mix	Has high potential for ocean tidal in-steam energy
Oil, Gas, and Minerals	7		Holds 3.48 trillion cubic feet of proven gas reserves as of 2017, equivalent to 31.4 x annual consumption
Biotechnology and Medicine		Basic research initiated in HEIs	High biodiversity offers high potential for medicine sources
Marine Tech and Env. Services			Unique archipelagic nature ideal as a marine technology testing center

Source: Azanza and David (2020)

The oceans also provide the majority of our daily food protein, amounting to 40 kg per capita per annum.

There are technical and logistical constraints, including the lack of scientific knowledge and capability, that impede the development of these Philippine blue industries. Other more commercially ripe technologies are still unsupported by existing government and inter-government policies. We also need to make sure that new arrangements for the development of these blue industries will also include protection of the biodiversity in the areas that may be impacted within and beyond areas of national jurisdiction.

Blue Economy Future Resources and Technologies

A key strategy for securing the natural capital of the global blue economy is the improved enforcement of adaptive strategies and management tools which are vital for its recovery. Marine Protected Area (MPA)/MPA networks can help preserve marine biodiversity, rejuvenate fisheries, and mitigate the effects of climate change (Gaines et al. 2010; Cabral et al. 2020). More than 1,800 MPAs have been established in the Philippines, but majority of these are small (<1 sq km), protecting less than 1% of coastal waters and less than 4% of coral reefs and associated critical habitats (e.g., seagrass beds and mangroves) in the Philippines (Cabral et al. 2014; Weeks et al. 2010). Unfortunately, many of these MPAs are not strictly enforced or well-managed (Alcala et al. 2008; White et al. 2014). Marine spatial planning has not been practiced well if at all in many areas in the country. Despite these shortcomings, there is growing advocacy to establish MPA networks (systems of many MPAs that protect a sufficient percentage of critical habitats) to boost fisheries productivity and conserve biodiversity in the Philippines (Horigue et al. 2012; Russ et al. 2020).

STIs are expected to play a crucial role in harnessing ocean resources for the blue economy, while ensuring sustainability and understanding how complex marine ecosystems will respond to climate change. Among these technologies are (Table 4.1_2):

- innovations in advanced materials
- subsea engineering and technology
- sensors and imaging
- satellite technologies
- computerization
- big data analytics
- autonomous systems
- biotechnology
- nanotechnology
- marine spatial planning
- circular blue economy

The application of emergent and convergent technologies in the Philippines—such as CAWIL.AI, an artificial intelligence (AI) coupled with underwater tools that enables detailed analyses and monitoring of coastal and marine ecosystems, and fisheries supply chains—is still at an early experimental stage (Naval and David 2016) and is thus a promising avenue for targeted research and innovation.

Table 4.1_2. List of Emerging Technologies for Sustainable Philippine Blue Economy

Blue Energy	Blue Food and Medicine	Blue transportation and Industries	Digital Blue Ecosystems	Blue Home Technologies	Blue Education and Tourism
Blue bioenergy through algal biofuel production	Blue biotechnology for pharmaceutical, cosmetic, food, feeds, and beverages.	Advance Material Research and Development	Mutli-sensor Imaging of Blue Ecosystems	Bioluminescent household and street lighting through biomimicry	Promoting blue ecosystem conservation via Internet of Things
Algal photobioreactors	Integrated Multi-trophic Aquaculture Precision aquaculture (monitoring using wireless mutli-sensors; robotics, mechanized)	Blue nano-materials	Autonomous monitoring system (e.g., autonomous underwater vehicles or Unmanned Aerial Vehicles, remotely operated underwater vehicles)	Rainwater harvesting	Carbon Neutral Resorts
Algal photovoltaics	AI and other STI to improve monitoring and management of fisheries and aquaculture	Smart Shipping and e-Boats	Web-based Mapping of Blue Environment S&T incubator and marine technology hub	Membrane technology for water treatment filtration	S&T incubator and marine technology hub

Table 4.1_2. Continued

Blue Energy	Blue Food and Medicine	Blue transportation and Industries	Digital Blue Ecosystems	Blue Home Technologies	Blue Education and Tourism
Microbial Fuel cell		Wave disc engines		Integrated co-processing technology for domestic wastes	Geo-tagging for migratory species which can be used for navigation avoidance and biodiversity ecotourism
Blue Biojet Fuel from Hydrothermal liquefaction Process		Ultra capacitor vehicles and watercrafts		Micro-hydro systems using rainwater in high rise building	
Integrated bio-refinery in palm oil mill		Carbon dioxide to carbon nanotubes conversion		Solar grey water disinfection	
Ocean thermal energy conversion (OTEC)		Carbon storage in building material		Nanotech improved Light Emitting Diode lightbulbs	
Underwater power grid technology and subsea power systems.		Bioremediation and phytoremediation for hazardous wastes		Bioplastics (Plastic from crops)	
Smart energy monitoring and network		Smart water monitoring Aerogel insulation technology		Rainwater harvesting	
Fuel cell		Electric and hybrid vehicles and watercrafts			
Biomimicry inspired wave and tidal energy		Autonomous vehicles			
Tidal InStream Energy Conversion (TISEC)		Carbon dioxide collector for vehicles			

Source: Naval and David (2016); Labao and Naval (2019); Azanza and David (2020)

Towards a Philippine Coasts and Ocean Framework and Strategy

Strategic, holistic, and trans-disciplinary coast and ocean science-related education is important to advance the blue economy and a national coast and ocean strategy. Further, a deep and wide review of relevant existing laws, policies, and practices that need to be changed, revised or even simplified should be the first milestone towards the achievement of an inclusive and sustainable “Prosperous, Archipelagic, Maritime Nation.”

This vision should be incorporated into basic and professional education, mass media, informal education, and the training of national and local policymakers, educators, and practitioners. Human resource development through scholarships, specialized training, university research programs, and partnerships will ensure the creation and application of blue knowledge. Apart from blue technology development and education, the implementation of laws and the promotion of good environmental governance are essential, as is compliance with legally-binding treaties under the United Nations and intergovernmental bodies relating to the use of ocean spaces (Azanza et al. 2017).

Integrated ocean management (IOM) is the overarching framework for a holistic, ecosystem-based, and knowledge-based approach to ensure the sustainability and resilience of marine ecosystems and coastal communities. To optimize the overall ocean economy, IOM guides the maintenance and further development of the effective sector-based management of ocean industries. Successful implementation of IOM requires an understanding of different contexts, including local knowledge, environmental conditions, and stakeholder engagement and stewardship in the adaptive management systems (Winther et al. 2020). The development and implementation of a Philippine Coasts and Ocean Strategy should be a top Philippine government priority.

SECTION 4.2
GOVERNANCE

In 1980, the Development Academy of the Philippines (DAP), the University of the Philippines (UP)-Population Institute, and the UP School of Economics collaborated to produce "Probing our Futures: The Philippines 2000 AD". The report offered alternative futures for the Philippines using extensive economic and demographic data. It proposed that the Philippines was "in for a generation of relative austerity" (DAP 1980).

Based on this assessment, the report pushed for self-reliance and participatory democracy as values that Philippine society must embrace to achieve its development aspirations. Decades later, despite significant economic strides, these virtues remain aspirational in view of social and political initiatives to address democratic challenges, youth welfare, Bangsamoro's concerns, and the aggression of China, as stated in earlier sections of this Foresight.

Good governance is necessary to address not only economic needs, but also to foster critical and democratic virtues (Graham and Plumptre 2003). To this end, scientific consciousness, critical thinking, and the ability to express oneself must be encouraged. Greater appreciation for the use of science and technology (S&T) in governance must be accompanied by a critical (re)thinking of history, politics, culture, and society, for the Philippine population to fully grasp the potential of democratic participation in an increasingly diverse—and still unequal—society. Doing so can challenge the spread of disinformation of and revisionist histories that uncritically celebrate authoritarianism. Filipinos must also gain and retain a deeper appreciation of the archipelagic and maritime nature of our geography, our relationships in ASEAN and ongoing aggression of China into Philippine territory.

Technologies are now available to secure the integrity of government institutions and our national territory in order to bypass clientelism in politics and enhance the accountability of public offices and government officials.

Select Technologies for Effective and Efficient Governance

Governance is the exercise of power and authority to implement a development agenda through "the management of a country's economic and social resources" (World Bank 1992). The World Economic Forum characterizes good governance with the following features (Bruce-Lockhart 2016):

- Openness, transparency, and integrity
- Performance orientation
- Effective collaboration

Effective and efficient governance is necessary to establish an environment of high workforce performance in both the public and private sectors. Strategic technologies can be harnessed for both the government and private sectors to provide quality services, minimize human errors, reduce unreasonable bureaucratic procedures and unnecessary expense, and ultimately achieve administrative efficiency and timely response. Reliable databases are also important to be able to provide timely information and timely decisions.

Below are some key technology areas that will prove useful towards promoting good governance:

Internet. There is a growing body of literature on the influence of the internet on governance. The study by Khazaeli and Stockemer (2013) indicates that access to the internet has a positive influence on government practices. Political information can be distributed through the internet and feedback from the citizenry will be available to the government. An informed citizen will enable transparency to be sustained, so public officials will be inclined to practice good governance.

National Identification System. This is a strategic technology to integrate different government services and facilitate efficient access among the public. Employing it in the voting process, for example, can render elections more credible—especially in areas vulnerable to corrupt practices, including double and ineligible voting. The national identification (ID) system can also streamline access to government services by removing burdensome additional requirements and documents. With the help of professionals in information technology (IT), data science, and engineering, these technologies can be harnessed to ensure that private data are secure and that government transactions are beyond reproach.

The success of the national ID system is contingent on accessibility and overall public trust in the integrity of the technologies involved. The state must push for greater reliance on IT and artificial intelligence (AI) to minimize discretionary interventions in government transactions.

Election Computerization. Aside from behavioral and management issues, clean elections will certainly benefit from technology that includes national voter registration systems; new methods of voting, such as the use of telephones and online portals; and the assurance of system integrity and of the correctness of computer programs. Software and hardware are already currently available that could provide the appropriate storage size; facilitate the pace of operations; and provide solutions that will assure the accuracy, integrity, and reliability of information and communications technology (ICT) and various attendant technologies.

A series of laws have been passed to regulate the conduct of a computerized election system in the Philippines (RA 8046, RA 8436, RA 9369). These laws provide the specific technologies to be used for the computerized election system, from voter registration to the reporting of election results. However, the system needs further improvement, as observers noted that the usual problems—e.g., voter disenfranchisement as voter lists became corrupted due to technological glitches—persisted despite the new technologies (Schaffer 2009).

National Defense Technologies. One important government role is the protection of Filipinos from national security threats. This involves the creation of a strong system of defense. There are many aspects of our defense system that need STI inputs, including:

- Secure and reliable communications systems
- Locally produced combat rations
- Survival technology for injuries and infections
- Technology to identify casualties
- Cyber-, spaced-based, unmanned, autonomous, and other complex military systems, e.g., hypersonic weapons (Stone 2020) and laser weapons (Lockheed Martin 2020)
- Unmanned vehicles and aerial systems
- Precision munitions
- Robust and secure military transport systems- land, air, and water
- Electro-optic/infrared countermeasures (Lockheed Martin 2019)

National Statistics System. To aid in decision-making, a robust and reliable national statistics system must be established involving technology for data-gathering, surveys, supporting statistical and numeric data services and sources, description, evaluation, and analysis of data to arrive at statistical patterns, trends, and relationships.

ICT-based Information and Documentation Services. Select technologies could be used to file, store, and retrieve documents from the civil registry, register of deeds, payment of fees and taxes, issuance, and the renewal of passports.

Forensic Services. Adopt technology to promote precision in crime detection, gathering of evidence, for combating cybercrime, and the distribution and use of drugs of abuse.

Customs Enforcement. Technology can be used to facilitate the rapid and precise detection and evaluation of goods in compliance with customs rules and regulations.

Humanitarian Emergency-Response Technologies. Remote sensing and drones are just a couple of technologies that could be used for disaster risk mitigation, estimation of extent of damage and to monitor environmental degradation. Casualties whose bodies have been damaged beyond recognition could be identified using DNA technologies.

Geographic Information Systems (GIS). This consists of a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface (NOAA 2020). This facilitates the visualization, analysis, and understanding of patterns and relationships, e.g., poverty mapping, cropping intensity patterns.

Cultural Heritage Preservation Technologies. This is the main concern of museums. The application of technology can enhance the experience while viewing museum exhibits using digital experiences. The technology for the preservation and authentication of museum pieces, historical and archeological artifacts are vital to the sustainability of the museum that are offered for public viewing.

Conclusion

The above list of select technologies is deemed to have a direct impact on the effectiveness and efficiency of governance in the public and private sector. While the burden of their use is on the government, the private sector must be aware and be part of the initiatives to use these technologies in advising and dealing with their publics.

The key goals of good governance—empowerment, inclusion, participation, integrity, transparency, and accountability—are realized only if workable STI solutions are adopted, drawn from experience (Sundaram 2015).

The realization of the aspirations of an archipelagic and maritime Filipino nation can be facilitated if technologies for good governance are harnessed to engender transparency and trust. Such an environment is vital for nation building and national well-being.

SECTION 4.3
BUSINESS AND TRADE

The access to and use of science, technology, and innovation (STI) have become vital to improving the production of goods and services, as well as to the facilitation of business and trade transactions. New products and processes are major factors in the growth of economies, and technical change is brought about by decisions of different economic units (Stokey 1995; Griliches 1992). Porter and Stern (2002) further observe that competitive advantage "must come from the ability to create and the commercialize new products and processes, shifting the technology frontier as fast as their rivals can catch up."

Economic Sectors

The Philippine economy is composed of three major sectors: Agriculture, Industry, and Services, each with its own sub-sectors as shown in Figure 4.3_1 (PSA 2020a).

It is reasonable to surmise that, as of 2018, the 334,522 formal establishments within the three sectors conducted their business using STI, one way or another. Services comprised the largest economic sector with 89.1% of the establishments, followed by industry with 9.9% and the remaining 1.0% in agriculture (Figure 4.3_2). Other indicators such as Total Employment, Revenue, Expense, and Value Added follow the same trend as the number of establishments, with agriculture trailing behind significantly (PSA 2020a).

The use of STI is evident in the specific activities of all three sectors, and the need for innovation to produce next-generation products is a big challenge to their competitiveness. In 2018, the services sector accounted for the highest value-added at 62.7%, while Industry and agriculture accounted for 36.5% and 0.8%, respectively, indicating the level of innovation in each sector. This should be a wake-up call to devote more attention to agriculture.

An example of the many opportunities for creating high-value products from agriculture is the use of biocellulose, known to us as *nata de coco*, for the vibrating membrane in high-end earphones that sold for as much as USD 6,000 each (Guttenberg 2013).

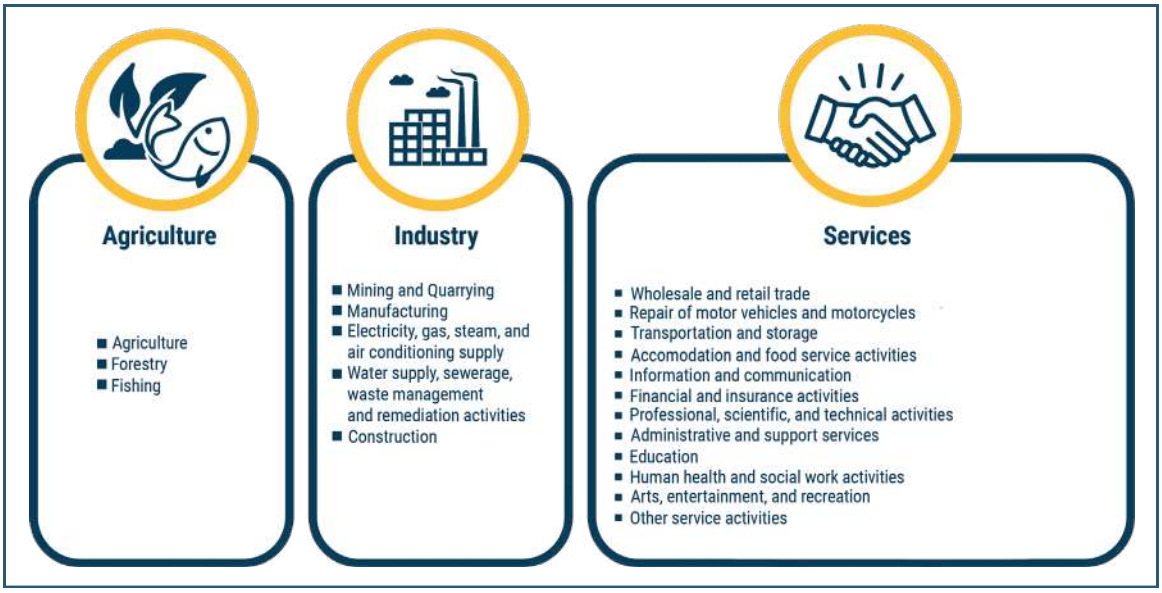


Figure 4.3_1. The Sectors and Sub-sectors of the Philippine Economy
Source: PSA (2020a)

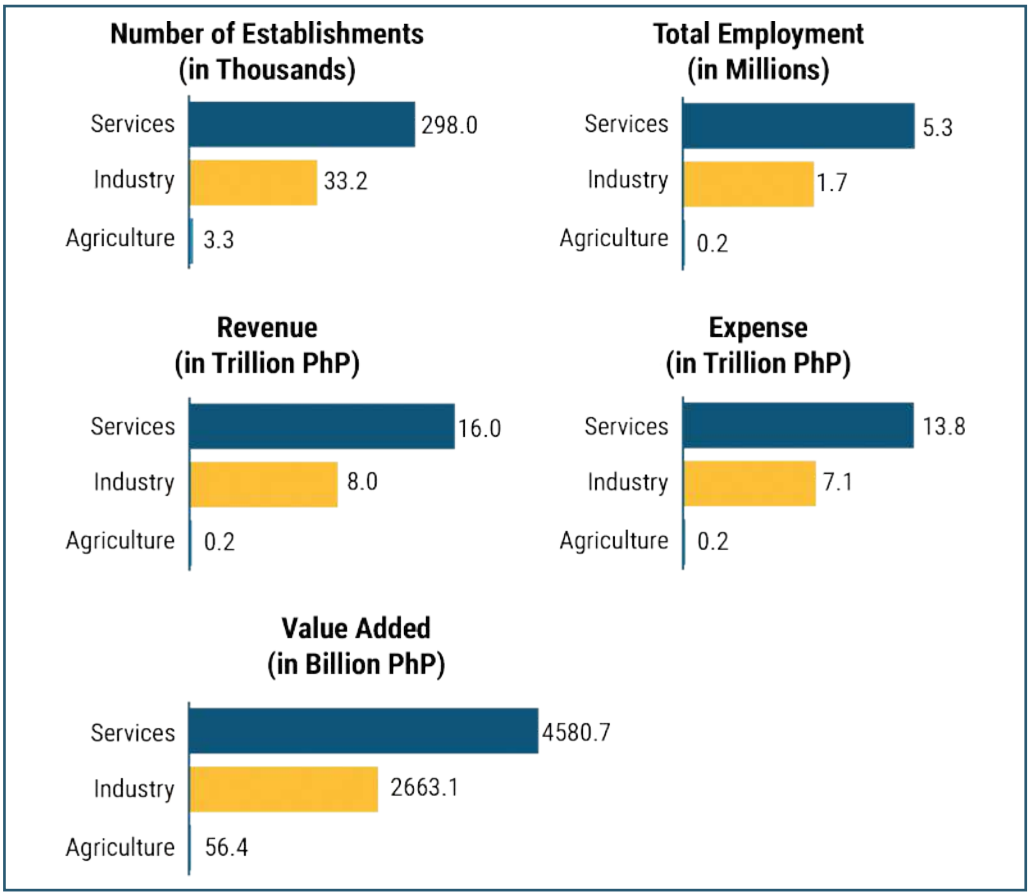


Figure 4.3_2. Selected Statistics on Major Economic Sectors, 2018 CPBI
Source: PSA (2020a)

Major Imports and Exports

Table 4.3_3 (PSA 2020b) shows the preliminary data about the growth of our ten top exports, which require intensive STI inputs. Unfortunately, apart from bananas and mineral products, the raw materials for the rest are imported and just assembled and packaged in the Philippines (PSA 2020b). Thus, the value-added is small, although the volumes are large.

Table 4.3_1. Top 10 Philippine Exports to All Trading Partners as of September 2020 Year-on-Year Growth

Major Commodity Group	Annual Growth Rate (%)
Gainers	
1. Cathodes and Sections of Cathodes, of Refined Copper	133.9
2. Other Mineral Products	73.3
3. Metal Components[1]	32.9
4. Chemicals	25.9
5. Electronic Equipment and Parts	24.3
6. Other Manufactured Goods	5.4
7. Electronic Products	0.8
Losers	
8. Bananas	-32.9
9. Machinery and Transport Equipment	-2.7
10. Ignition Wiring Set and Other Wiring Sets Used in Vehicles, Aircrafts, and Ships[2]	-1.0

Source: PSA (2020b)
Notes: Table shows preliminary data as of September 2020
[1] excluding brakes and servo-brakes
[2] consists only of electrical wiring harness for motor vehicles

The growth of our top 10 imports from our trading partners are shown in Table 4.3_4 (PSA 2020b). As noted earlier, these are mainly semi-processed or semi-assembled materials or completely built products brought in for our factories to either assemble or package mainly because of competitive labor costs but resulting in low value-added exports.

We must continue to pursue the development of higher-valued products from our manufacturing and agri-business sector. It might be worth our effort to establish our niche in bioindustries using materials that we can derive from the farm, the forest, and the marine environment. The earlier example of a bio cellulose product from *nata de coco* might be worth pursuing.

Given the profile of products that we import and export, the subsequent discussions will cover the concerns related to enhancing our economic efficiency and facilitating trade.

Table 4.3_2. Top 10 Philippine Imports from All Trading September 2020

Major Commodity Group	Annual Growth Rate (%)
Gainers	
1. Telecommunication Equipment and Electrical Machinery[1]	2.6
2. Electronic Products	2.4
Losers	
3. Transport Equipment	-53.0
4. Mineral Fuels, Lubricants, and Related Materials	-51.4
5. Industrial Machinery and Equipment	-23.3
6. Miscellaneous Manufactured Articles	-23.0
7. Plastics in Primary and Non-Primary Forms	-22.1
8. Iron and Steel	-10.7
9. Other Food and Live Animals	-4.4
10. Cereals and Cereal Preparations	-0.2

Source: PSA (2020b)
Notes: Table shows preliminary data as of September 2020
1 includes telecommunications and sound recording and reproducing apparatus and equipment

Enhancing Economic Efficiency

Economic efficiency is fostered by many factors in our national life: governance in both the public and private sector, infrastructure, transport, energy, health, education and training, and international relations. Other sections of this report deal largely with the issues related to the said factors and will no longer be discussed here. Suffice it to say that all these have to be managed on a whole-of-government approach.

With regard to governance, a functional innovation ecosystem relies on a robust symbiosis involving industry, academia, and government. Close links with industry result in a departure of university researchers from a technology-push mindset to a more market-pull orientation. In 2015, the Philippine Government University Industry Research Roundtable (PGUIRR) was convened under USAID's Science, Technology, Research and Innovation for Development project based on a similar US model. This group, composed of leaders from industry, universities, and relevant government agencies, was convened to stimulate closer collaboration between the research community and the eventual end-users, with government playing the role of a catalyst. In addition, government can also play the role of influencing industry to account for externalities—e.g., impacts of climate change and natural disasters—in their decision-making. Establishment of a permanent group based on the PGUIRR concept, the Science and Technology, Academe, Industry Research Roundtable, is proposed to ensure seamless cooperation among the three key sectors.

The recently-promulgated Philippine Innovation Act (RA 11293) is an important initial step towards providing an enabling regulatory environment for translating new technologies into new wealth. In addition to adoption of new technologies by established players, technology-based start-ups can assume an important role in translating research output into economic value.

While the Philippines has yet to establish a track record of translating scientific research into commercial products, the prospects can be improved dramatically by considering the business community's vital role as both beneficiary and enabler of innovation.

Trade Facilitation

Globalization has opened up trade among many economies. Free trade areas organized by various aggregations of countries are designed to overcome the barriers that have inhibited the free exchange of goods and services. Cross border flows of goods have promoted compliance with standards in terms of product quality through Mutual Recognition Agreements (MRA) to facilitate market access and encourage harmonization of compliance standards to protect the consumer. In the case of services, the MRA refer to the qualifications of professionals and skilled labor so they can practice their professions in the countries that are parties to the agreement. For technical and scientific professionals as well as for skilled labor, their education and training both at the tech-voc centers and the higher education institutions will determine the fitness of their qualifications with the standards. This is covered by the section on talent development and retention.

The National Quality Infrastructure

Trade is one of the major routes in providing livelihood and reducing poverty. However, our national capacity to trade is determined by our competitiveness. In 2019, we ranked 64th out of 131 countries, sliding down eight points from our 2018 ranking in the World Competitiveness Index .

The determining factor for the tradeability of Philippine-made products is their quality. According to Botor and Echanove (2011), among many other measures, a fully functional National Quality Infrastructure (NQI) will "help ensure that the country's products and services will comply with international standards and the conformity assessment requirements of trading partners, which could be barriers to trade." The same report notes that our "inadequate and poor quality infrastructure diminished the country's overall competitiveness and its capacity to attract investments."

The NQI that is operated by both the public and private sectors consists of the following physical and organizational structures:

- Metrology
- Product standardization
- Testing
- Certification
- Accreditation

Transactions have grown exponentially due to globalization, facilitated by rapid innovations in information and communication technologies. These technologies have been useful in disseminating updated information, especially about the regulatory regimes and product standards of trading partners.

The technologies for the detection of various goods have also advanced significantly such that high-throughput testing equipment with high precision and sensitivity have been developed for many types of products. These testing facilities not only determine compliance with product standards but also detect imitation and fake products that violate intellectual property rights. Also, the entry of a good number of contraband and smuggled products as well as many drugs and explosives can now be detected with accuracy.

To summarize, the following are the technological inputs to our NQI:

- High speed, high-capacity computing
  - Trade and business information infrastructure at the internal and external
  - Artificial Intelligence
  - Big Data
  - Data science
  - Automation
- High-Throughput, large scale, systematic automated chemometric methods
  - Detection
  - Identification
  - Quantification
  - Monitoring
- Analytical Methods for biologicals, gene products, substrates, and cell activities
  - Assessment for the introduction of exotic species, especially invasive ones
  - Assessment for the introduction of GMOs and their products
  - Biosecurity - detect entry of biological warfare materials
  - Biosafety - detect entry of harmful, unsafe and infected food products
- Emerging technologies for product inspection during transport (Rouhi 1995)
  - Computed tomography: using x-ray to reconstruct a cross-sectional image of an object
  - X-ray scanners
  - Nuclear Quadrupole Resonance: detection of quadrupole moments of elements used in explosives
  - Neutron Analysis: Materials bathed with neutrons will emit gamma-rays whose energy and intensity are characteristic of component elements like nitrogen.
  - Vapor detection methods: characteristic vapor emitted by material
- Recycling Technology - materials derived from goods and services and obsolete products

The foregoing discussion focused on major concerns of business and trade, especially towards achieving competitiveness. Various technologies are indicated in other sections of this Foresight to support public and private sector efforts to compete in the global market. Niches must be developed for Philippine products to thrive in an intensely aggressive market.

However, productivity must be balanced by both economic and environmental sustainability. Even at the earliest stages of product development, the environmentally-sound recycling of by-products, waste materials, and obsolete products must already be designed into the manufacturing process and product lifecycle.

SECTION 4.4
INFORMATION AND COMMUNICATIONS TECHNOLOGY

Information and Communications Technology (ICT), as defined by the Technical Education and Skills Development Authority (TESDA) (2020) refers to "technologies associated with the transmission and exchange of data in the form of sound, text, visual images, signals or any other form or any combination of those forms through the use of digital technology. It encompasses such services as telecommunications, posts, multimedia, electronic, communications, broadcasting, and information Technology (IT)." TESDA further states that in terms of global trends, "IT resulted in revolutionizing the way people communicate and for governments and firms to interact and conduct business. The ICT revolution, specifically the Internet, alters the way people around the world communicate, live, learn, play, and work."

In 2016, RA 10844 created the Department of Information and Communications Technology (DICT) as an Executive Branch at the Cabinet level, for planning and promotion of the ICT agenda of the Philippines.

However, a lot of human and physical resources will be needed over the next 30 years to fully realize ICT's potential to government at all levels—provincial, city, and municipal—and to private firms. As indicated in Table 4.4_1 below, 76% of households do not have computers, 82% are without Internet connections, 92% are without a fixed telephone line, and 76% are without even a communal cellphone (DICT 2019).

The Internet, which started as Arpanet, was created by the United States Defense Department in 1969 (Lukasik 2011). Wireless transmission would not be possible without the profound development of electromagnetic theory by nineteenth century physicist James Maxwell. Communications media such as radio broadcasts, television broadcasts, radio and television receivers, smart phones, and communication to and from devices connected to the Internet of Things (IoT), etc. are prime examples where wireless communications are utilized.

Table 4.4_1. Result of Survey to Filipino Households on Access to Electricity, Radio, Television, Telephone/Cellphone, and Internet as of 2019

Electricity		Type of TV Service	
With electricity	95%	Analog TV	40.9%
Without electricity	5%	DTH Satellite Service	16.8%
Radio		Analog TV	13.9%
DTH Satellite Service	47%	DTH Satellite Service	23%
Without radio	53%	Smart TV	4.5%
Television		**Computer**	
With TV	79%	With computer	24%
Without TV	21%	Without computer	76%
Type of Computer (with access to computer)		**Internet**	
Laptop	50.6%	With Internet	18%
Tablet	30.2%	Without Internet	82%
Desktop	19%		
Telephone/Cellphone		**Type of Internet Connection (with Internet access)**	
With Fixed Telephone line	8%	Wired Broadband Network	53%
Without Fixed Telephone line	92%	Mobile Broadband Network	21.1%
With Communal Cellphone	24%	Wireless Broadband Network	21.8%
Without Communal Cellphone	76%	Satellite Broadband Network	2.9%

Source: DICT (2020)

Another enabler of the Internet is the creation of a mathematical theory of communications by Claude E. Shannon (Shannon 1948; Shannon and Weaver 1949). This theory is the foundation of modern communications and, together with electromagnetic theory, is the technical foundation of wireless telecommunications including the Internet and ICT.

A full realization of the benefits of ICT will necessitate the development of Digital Transformation (DX) (Torres 2020). DX is the creative conversion of government offices, business enterprises, and other organizations, through utilization of ICT, to enable them to provide new services not possible without ICT, and to make them more efficient than before the conversion. It is a mindset change to utilize technology to imagine information flow as judicious retrieval from appropriate databases. DX is a major thrust in the world. In March 2020, the Digital Transformation Institute was created as a consortium of major research universities in the United States with the Microsoft Corporation (C3 AI 2020a). The consortium provides an integrated data base of many scattered data bases on COVID-19, made available free to the world (C3.ai DTI 2020).

A government agency, business enterprise or other organization that has been converted using DX will be called a Digitally Transformed Entity (DTE). Inspired by natural ecosystems, a group of DTEs interacting with each other, mutually benefiting each other, or promoting the greater good of the group, is called a Digital Ecosystem (DECS) (Torres 2020). The DECS is capable of self-organization and sustainability, inspired by natural ecosystems. A natural ecosystem is "a community of living organisms in conjunction with the nonliving components of their environment interacting as a system." An ecosystem is characterized by its "network of interactions among organisms, and between organisms and their environment" (Torres 2020). A DTE or a DECS may have a Digital Twin (DT) (Torres 2020). A DT is a mathematical approximation of a DTE or a DECS in terms of computer algorithms and software systems. The parameters of the DT are calibrated using real data from the past up to the present, of a DTE or a DECS.

Key Trends, Needs, and Gaps in Science, Technology, and Innovation

The Philippine Internet was established in 1994 (PHNET 2020), funded by the Department of Science and Technology (DOST). The Philippine Research, Education, and Government Information Network (PREGINET) was set up exclusively to connect selected institutions (PREGINET 1998). However, due to exponentially growing demand over the last 25 years, the Philippine Internet infrastructure is woefully inadequate for the country's current needs.

In the current era, made more prominent by the COVID-19 pandemic, some employees work from home (WFH) while others work from office (WFO). How can WFH/WFO workers in the same enterprise or in different enterprises work together? Although there is ICT in the Philippines, demand far exceeds the capability of the infrastructure. Telephone and data telcos do not provide enough broadband and speed which are needed to be able to convey and access high quality information both here and abroad.

The foregoing background on ICT, including global trends as well as Philippine conditions, suggests that ICT is a linchpin in this Foresight for achieving proficiency in STI.

The Technology Forces

Briggs and Buchholz (2019) describe nine macro technology forces that are changing our world. The first three of these are developments which emerged some years ago and are now enabling technologies that support innovation today and in the future. These are:

Digital experience. These technologies will evolve from the business-customer interface technologies (social, mobile, web) to the digital experience permeating not only the customer-business interface but also all digital transactions within the entire business. As a result, business strategy will rely increasingly on human-centered design and user engagement.

Analytics. Use of data will evolve from descriptive, to predictive, to prescriptive. At present, data analytics is used mostly to get patterns from historical data. However, companies will want to make predictions and also recommendations on how to act based on those predictions.

Cloud. In the last decade, no single technology trend has so dominated the arena of enterprise IT as the cloud. In its most common and simplest form, cloud is a means for lifting and shifting workloads, or simply as the extension of the data center. In the future, however, the potential value of the cloud for achieving long-term growth and developing innovation will emerge. Customers may turn to the cloud for access to artificial intelligence (AI), blockchain, digital reality, quantum computing, etc.

The disruptive macro technologies that were identified by Briggs and Buchholz (2019) are the following:

Digital reality. Comprising augmented reality, virtual reality, mixed reality, the Internet of Things (IoT), and immersive/spatial technologies, this macro technology is evolving beyond keyboards and touch screens to offer new ways by which humans interact with data, technology, and each other.

Blockchain. This technology was originally invented in support of cryptocurrencies (Bitcoin). It is essentially a database duplicated, shared and updated by a network of computers. Its disruptive potential lies in the fact that it could replace certain business models. For example, it could eliminate businesses that earn from charging small fees for a transaction, such as credit cards, bank services (Rosic 2020).

Cognitive technologies. Examples of these technologies are machine learning, neural networks, robotic process automation, bots, natural language processing, and AI used not only to visualize information, but also to augment and automate human response to information.

The following last three macro technologies address the core legacy of enterprises. Their evolution in the coming years is said to provide the foundation on which the other macro technologies will be built:

Business of technology. In this world of rapid innovation, companies are becoming more and more like similar to technology companies. The challenge is to integrate technology into business strategy and to re-engineer IT organizations.

Core modernization. Enterprises have been re-engineering their core systems to keep up with advancement brought by technology. In the future, these reconfigured platforms are expected to bring innovation and growth.

Cyber risk. So far, cyber risk is the concern of IT and technical departments. It is expected that its importance to all stakeholders in the entire enterprise will grow. Thus, cybersecurity will be integrated in all aspects of the transformation of an enterprise.

Panetta (2017) noted three technological mega-trends: AI everywhere, transparently immersive experiences, and digital platforms. The descriptions of these techno-trends appear similar to the emerging macro technologies listed by Briggs and Buchholz (2019). Emerging technologies within these trends were identified by Fitzgerald (2020), Forrester (2020), and Maddox (2020) as follows:

1. Artificial intelligence
2. 5G
3. Internet of Things
4. Serverless computing
5. Biometrics
6. Augmented reality/virtual reality
7. Blockchain
8. Robotics
9. Natural language processing
10. Quantum computing

Singh (2020) mentions many of these and adds some more specific technologies: autonomous driving, 3D print and cybersecurity.

Quantum Computing deserves a special mention here. Conceived theoretically in the 1980's and experimentally tested in the 1990's, this technology is being pursued by Google (in collaboration with NASA) and IBM. Based on patent filings, other companies in the quantum computing space are D-Wave Systems, Nokia/Alcatel, Honeywell, Microsoft, Northrup Grumman, Boeing, HP, NTT, Hitachi, Toshiba, and NEC (Scanlon et al. 2020).

Current technology is still not fault-tolerant and has yet to convincingly demonstrate what is referred to as "quantum supremacy" or, loosely, the ability to solve problems that classical computers cannot. Yet investment in the technology is booming with no less than the US government announcing in 2020 a USD 1 billion investment in AI and quantum computing (Vincent 2020). Capital for mainstream companies has increased four times in 2017-2018 (Gibney 2019). Startup funding reportedly grew from USD 4 million in 2015 to USD 300 million in 2020 (Carson 2020). These trends in investment point to at least growing confidence that quantum computing can be brought from academia to the market in the next two or three decades. The patent data also reflects the growth in investment.

Scanlon et al. (2020) report a 450% increase in the number of patent families, mostly in qubit technology and hardware. Most of these patents are from the US. Japan runs second although China surpassed its patent filings in 2014. Chinese interest in quantum computing lies in the area of cryptology.

Fundamentally, this surge in investments and innovation is inspired by the computing speed and ability to solve complex problems that classical computers cannot match. These advantages are likely to disrupt existing business and industry, and even the mega-trends and techno-forces identified. The potential for creating new industries is also high. For the moment, there appears to be a consensus on the possible impacts on other technologies: AI, machine learning, computational chemistry, drug design and discovery, cybersecurity and cryptography, financial modeling, optimization, and climate science (Das 2020; Dilmigani 2020; Gossett 2020; Honeywell 2020; Jackson 2017; Scanlon et al. 2020).

The macro forces are significant by themselves, but they are also very important in that they are likely to transform other technologies. As these macro forces evolve, they will probably bring about advances in other, more main-stream technologies. A digital future is predicted which social, mobile, cloud, big data and demand for access anytime anywhere to information will drive transformation of business models, mobile device adoption, business-customer relationships, market context and competitive landscape and cybersecurity issues (EY 2015). Atkinson (2016) adds that people will be increasingly connected and suffer loss of privacy and that new business models will emerge as a result of digital technologies and interconnection.

Telecommunications

Technologies in the telecommunications/ICT sector have rapidly developed in the past two decades. The wireless revolution, referred to in an early part of this section, which ushered in the internet, digital telephones, and digital media, has greatly accelerated the development of technologies to connect remote areas.

The challenge of creating an information infrastructure based on wireless and digital technology has intensified activity towards building a telecommunications/ICT backbone that will provide basic connectivity especially for the rural and remote areas (ITU 2019). The drive for inclusive development, referred to as the "last mile connectivity," has pushed both the private and public sector to overcome the challenges of rugged terrain and limited power supply to connect these usually isolated areas (ITU 2019).

Technologies for Telecommunications Infrastructure

The International Telecommunications Union (ITU) Study Groups (2019) took into account the existing and current trends in backbone infrastructure to include the following:

- Wireline communication infrastructure - copper or glass fiber-based terminating in a fixed location
- Fiber-optic cables - made of transparent glass or plastic fibers to transmit data using pulses of light and can support high-speed transmission compared to copper-based wirelines
- Wireless technology - uses telecommunications towers to support cellular communication antennas
- Submarine cables connecting continents, with around 378-420 submarine cables currently installed all over the world

Trends in Telecommunications/ Information and Communications Technology Infrastructure

The increasing demand for high-speed internet connectivity has triggered the need for more telecommunication towers, especially those powered by renewable energy like solar and wind. The ITU Study Group (2019) estimates that there are 4 million towers installed globally and is expected to increase as the 5G networks are rolled out.

Submarine cables are still considered the more reliable backbone for global connectivity while the towers are more practical for land communications.

Satellite telecommunications are still the best choice to connect isolated places, oceans, deserts, and areas often hit by natural disasters. Telecommunications for emergency situations still rely on satellite technology.

Last-Mile Connectivity

The available solutions to serve users in rural and remote areas are possible in the presence of possible backbones as follows (ITU 2019):

- Wired systems - uses copper wires and optical fiber offers high information capacity but requires amplification over long distances.
- Traditional wired local area networks - uses copper coaxial cables, modified to support higher bandwidths and improved modulation; amenable to enhancement to support high-speed transmission.
- Community antenna television systems (cable television systems) - expanded to provide communication in two directions but with limited user capacity.
- Optical fiber - high-capacity, high performance, low-error rates in transmission but high costs confines installation in urban areas; not prone to theft, unlike copper wirelines.
- Wireless systems - affected by terrain, buildings, weather conditions, but more reliable
- Light waves and free space optics - uses high frequency shorter waves, allows high data transfer rates but limited by obstructions
- Radio frequency or wireless radio systems - low information capacity used for facsimile and radio teletype
- Satellite communications - spread over large geographical areas, high information capacity and can accommodate many sharing users but still beset by high costs.
- E-line - uses single central conductor transporting energy in a plain wire and can support high information capacity range frequencies.

The trends in last-mile connectivity are as follows:

- Wi-Fi Technology - Wi-Fi hotspots supporting local area networks can be located where the community usually converges such as markets, shopping centers, school campuses and homes. Effective only if the backbone landing is near.
- High altitude platform systems and unmanned aerial vehicles (UAVs) - serve as mobile base stations to provide connectivity, solar powered and used for surveillance and monitoring during humanitarian emergencies; including use of balloons.
- Mobile virtual network operator model - small operators use the infrastructure and networks of larger operators.
- Business regulatory models and policies - develop policies for effective last-mile connectivity for rural and remote areas.
- Community network model - very small or medium scale networks within and managed by communities.
- Hybrid model - combination of large operators who provide capacity to connect to Internet and small operators to provide last-mile connectivity.

Enabling Environment

These technologies can be made to work only if both the government and the private sector collaborate to provide connectivity in an inclusive manner. Regulatory requirements, tax and customs duties, and the ease of doing business are vital to success in providing connectivity to all. Market forces usually do not address last-mile connectivity such that the government should partner with the private sector to ensure the deployment of a broadband network infrastructure for rural and remote communities. There are technologies available to effect inclusive connectivity. Both the public and private sector should ensure the availability of the human resources to manage and maintain a functional information infrastructure for an archipelagic and maritime country like the Philippines.

SECTION 4.5
SCIENCE EDUCATION AND TALENT RETENTION

Developing and Retaining Talent in Science, Technology, Engineering and Mathematics (STEM): Towards a Relevant, Robust and Resilient Knowledge Infrastructure

Edwards (2017) defines knowledge infrastructure as the "robust network of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds" and consists of schools, colleges, universities, and research institutions, journals and books, the information infrastructure, institutions that collect, process, analyze and distribute data, museums, media, and others that are engaged in the generation, sharing and maintenance of knowledge. As Rockstrom et al. (2009) noted, there exists "much more data and much better understanding not only of the natural world but also of human economies, population, wastes and nearly everything else."

Human resources in science, technology, engineering, and mathematics (STEM) perform a vital role in enhancing, maintaining, and monitoring the knowledge infrastructure — especially in STEM. As Romer and Griliches (1993) put it:

"Ultimately, all increases in standards of living can be traced to discoveries of more valuable arrangements for things in the earth's crust and atmosphere... No amount of savings and investment, no policy of macroeconomic fine-tuning, no set of tax and spending incentives can generate sustained economic growth unless it is accompanied by the countless large and small discoveries that are required to create more value from a fixed set of natural resources."

Due to the rapid developments of knowledge in STEM, such as automation and AI, the STEM talent pool has to learn to retool, to handle more complex tasks, and to work with and maintain machines so that tasks can be performed reliably and accurately (Tan and Tang 2016; Acemoglu and Restrepo 2017).

Return on Investment on Human Resources

The development and retention of talent in STEM in the Philippines is of vital importance in the context of the knowledge infrastructure that will enhance and sustain our development agenda. We shall devote our discussion to the educational system that should provide opportunities for STEM talent to develop and flourish.

In preparing for the year 2050, the weaknesses of our STEM talent development and retention schemes in the Philippines need to be identified. Several studies clearly indicate the need to improve and balance the regional distribution of our STEM talent development programs starting from K-12 up to those that lead to master's and doctoral degrees and vocational-technical education (Patalinghug 2003a, 2003b; di Gropello et al. 2010; Magno 2011; RTI International 2014; Manasan and Parel 2014; Manasan 2015; Bevins and Price 2015; DOST-SEI 2015; Raymundo et al. 2017; Albert et al. 2017; Quismorio et al. 2019).

There are two most critical "imbalances" that need to be addressed, urgently, when it comes to human resources in STEM: (1) the need for higher numbers (critical mass) of well-trained scientists and engineers than managers and administrators, and (2) equitable distribution of science and technology (S&T) human resources, and consequently, of research and development (R&D) resources, in the regions.

Determining the Critical Mass of Science, Technology, Engineering, and Mathematics Human Resources

One of the urgent tasks is to review the estimates that have been used as targets for building the critical mass of STEM Human Resources in the country. The basis of UNESCO data with regard to the critical mass of R&D personnel per million population that has been used as a target must be reviewed because the figure appears to be too low. Furthermore, the indicator is confined to the R&D sector, whereas STEM activities also include the provision for services like STEM education, testing laboratories, weather forecasting, seismological monitoring, and communication to enhance public understanding of science. We need a more realistic estimate of our targets to make sure that our current skills shortage will be corrected.

It is also evident that, globally, there is an increasing demand for STEM workers, from skilled technicians to highly trained faculty and researchers. Thus, it may be an understatement to say that we have to make sure that our initiatives to build the corps of STEM talent in the Philippines must be competitive.

Science, Technology, Engineering, and Mathematics Talent Development in the Philippine Knowledge Infrastructure: Schools, Colleges, and Universities

Basic Education in K-12. STEM talent development in the Philippines formally starts in Grade 3. The study of the STEM curriculum in K-12 by AusAid-University of Melbourne and SEAMEO-INNOTECH (2011) indicated major weakness both in the content and facilities for STEM instruction. These findings were confirmed by Manasan and Parel (2014) and Albert et al. (2017). Vea (2020) noted that for specialized STEM education, the Department of Education established 609 Special Science Elementary Schools (SSES).

For STEM education in Grades 7-12, there are five categories of public high schools that are geared towards specialized STEM curriculum. They are as follows (Vea 2020):

- 686 Science, Technology, and Engineering (STE)-Implementing Schools that have one or two special science sections per grade level
- 58 legislated science high schools
- 15 regional science high schools
- 30 public city science high schools
- 16 regional campuses of the Philippine Science High School System

In addition to these 128 publicly funded science high schools, there are 256 privately-owned science high schools.

A review conducted by Bevins and Price (2015) indicated the need to improve the quality of materials, the facilities, and the teaching of the science high schools. To ensure that there is a healthy number of feeders into the science high schools, the primary STEM curriculum should be strengthened to build the foundational scientific, mathematical, and thinking skills for an intensive science high school curriculum. For the requirements of the 21st century, coding and computer programming skills are being introduced in primary grades, and these curriculum upgrades should be considered in the Philippine basic education sector.

For the science high schools, including the Philippine Science High School, a review of the curriculum is in order as well as the recruitment of highly qualified instructors in STEM. Faculty development programs must be sustained with opportunities for retooling. For the senior high schools, research requirements must be reviewed, and the research supervisors must be carefully chosen so as not to waste time and materials.

Serious attention should be accorded to the quality of instruction in both the private and public science high schools because they are the feeders to the STEM courses in higher education. The poor qualifications of STEM teachers have been identified as a problem that must be addressed with urgency. To compensate for the loss of good STEM teachers who have gone abroad we need to revise our qualification standards and adopt a more supportive working environment.

STEM in Philippine Higher Education Institutions. Vea (2020) analyzed the landscape of STEM education in Philippine Higher Education Institutions (HEIs) by looking at data for the school year 2016-2017. The study indicated that the 1943 HEIs offer 3912 undergraduate STEM programs, 611 STEM programs leading to a master's degree, and 94 STEM programs leading to a doctoral degree, indicating a significant lack of vertical articulation resulting in lesser fields of study available for those interested to pursue a master's or doctoral degree. Engineering and technology programs attract high enrollments, but the science and mathematics programs continue to be undersubscribed. The same picture is true for the number of graduates, with information technology producing 36% of the 110,011 STEM graduates for the school year 2016–2017.

The picture is bleak, to say the least, in the number of enrollment and graduation for the master's and doctoral degrees with only 1313 and 122, earning the master's and doctoral degrees for the said school year. Some regions did not even have a single doctoral graduate for the school year. Also, during that school year, there were no graduates for the doctoral degree in critical areas of specialization like Botany, Marine Biology, Microbiology, Meteorology, and Geology, among others.

In addition to concerns on building this critical mass, issues on the quality of instruction—especially related to laboratories for teaching and research in STEM at the undergraduate and graduate levels—need to be addressed (Manasan and Parel 2014; Raymundo et al. 2017; Albert et al. 2017; Quismorio et al. 2019; Tutor et al. 2019). Multidisciplinary research programs must be encouraged.

State of Doctor of Philosophy Programs in STEM. Saloma (2016, 2020) analyzed the capability of the Philippines to produce its next generation of scientists and researchers towards the year 2050 focusing on the production of PhD graduates in STEM rather than on tracking the number of full-time equivalent researchers in the country since the metric is fraught with sampling concerns (Saloma 2020).

In AY 2019–2020, the Commission on Higher Education (CHED) accredited a total of 1,975 HEIs. These include 112 publicly funded state universities and colleges, and the rest are private HEIs which accounted for 87.5% of the institutions (CHED 2020). Less than 1% of HEIs have tenable STEM PhD programs due to the lack of qualified PhD faculty members to teach graduate courses and supervise the dissertation research of PhD students, coupled with the complexity and high cost of starting and operating a STEM research laboratory. The scarcity of PhD supervisors is impeding the graduation of more STEM PhD students. From AY 2003-2004 to AY 2019-2020, the number of PhD faculty members in all academic disciplines increased at a paltry rate of 0.34% per annum. Only accredited HEIs could grant doctoral degrees. On average HEIs produce yearly only about a hundred STEM PhD graduates, while producing 1,532 new lawyers (period: 2000–2019), 1,924 new certified public accountants (2000–2019), and 2,875 new medical doctors (2000-2016) (Saloma 2016, 2020).

Programs are in Place to Improve STEM PhD Production in HEIs. An example of a purposive doctoral degree program is the University of the Philippines Diliman (UPD) College of Engineering's (CoE) Engineering Research and Development for Technology (ERDT) Program. The ERDT has improved COE's PhD production to 12.8 ± 3.68 per year from AY 2010-2011 to AY 2018-2019, which is higher than the 30-year College of Science (CS) average (12.53 ± 3.8). It is noted that as of July 2018, the CoE had 78 faculty members with PhDs while CS had 168.

Another program is the Advanced Science and Technology Human Resource Development Program (ASTHRDP). Both ASTHRDP and ERDT, which are funded by the Department of Science and Technology (DOST) are instrumental in growing the PhD production at a yearly rate of +41.38%. A total of 1,927 PhD scholarships was planned for 2020 as compared to 302 in 2008 (Biyo 2019). The number will swell to 129,500+ in 2050, if the growth rate is maintained.

However, the real success of a STEM PhD production initiative is not measured by the number of scholarships awarded, but in the number of PhD scholars who graduated. The anemic increase rate in the number of STEM PhD faculty members as research advisers would result in fiercer competition for dissertation research supervisors among future scholars. The case with UPD and CS reveals that the hiring of more PhD faculty members would not automatically lead to a rise in STEM PhD graduates.

So far (2008–2018), the PhD graduation rate of the ASTHRDP and the ERDT is 53.97% (Saloma 2020), which is likely to worsen going forward if the scarcity of PhD supervisors continues. Thousands of future PhD scholars will be at risk of failing and face the dire prospect of reimbursing the government for the cost of their scholarship. There are no redundancies in the PhD degree programs offered by the ASTHRDP and ERDT partner HEIs and withdrawing scholarship support to an underperforming program will only eliminate the possibility for long-term development of critical expertise. For example, the Philippines has yet to produce a PhD Geology graduate in the 21st century.

Novel strategies are needed to enlarge the pool of PhD supervisors. HEIs may consider the successful mentoring of a PhD student a pre-requisite in the grant of tenure and cross-rank promotion, especially to full professorship. Professor emeriti and seasoned professors with a proven track record, may be tapped to serve as full-time PhD supervisors beyond the prescribed retirement age.

Successful mentoring of STEM PhD students should be given more weight in coveted lifetime recognition programs such as professor emeritus appointment and NAST PHL membership. Access to STEM PhD degree programs should be made free to qualified BS graduates and advanced STEM manpower programs should be managed with more attention to detail and evaluated regularly for possible structural weaknesses.

Technical and Vocational Education and Training. The role of skilled trades and crafts workers in the discovery and utilization of technology is one of the critical factors in a functional national innovation system. The National System of Technical Vocational Education and Training (NSTVET) under the Technical Education and Skills Development Authority (TESDA) is mandated to ensure access to opportunities for training and continuous upgrading of skills or up-skilling of trades and crafts workers.

NSTVET is designed to respond to three types of clients: (a) the unemployed; (b) the currently employed who want to increase their income; and (c) the employed who want to re-tool (Orbeta and Esguerra 2016).

NSTVET is conducted through programs that are school-based and center-based, enterprise-based, and community-based. Schools and centers, including TESDA, directly deliver training. The Dual Training System and the Apprenticeship Program are conducted within a company. The Community-based programs are implemented by the Local Government Units or non-government organizations.

As of July 2015, there were 4,609 accredited schools and centers offering 20,329 programs. Tourism, ICT, and health and social and community development are the most popular training programs, followed by construction, automotive and land transportation, and metals and engineering. Company-based programs involve 421 firms offering 1,208 programs with health, social, and other community development services, and tourism as top choices (Orbeta and Esguerra 2016).

The trends in enrollment and graduation vary according to the delivery mode. It is noted that the institution-based mode has the highest enrollment and graduation, while the enterprise mode is lowest in both. It is anticipated that the demand for training will increase over the years as the demand for skilled workers is rising worldwide (Orbeta and Esguerra 2016).

In a study involving ASEAN countries, including the Tan and Tang identified (2016) common skills challenges confronting these countries and proposed that the private sector be given a bigger role to meet the challenges with the following corrective measures:

- Provide a clear roadmap to meet skills challenges
- Revamp curriculum to emphasize STEM, Technical and Vocational Education and Training (TVET), and soft skills training
- Deepen school-industry links to improve the employability of graduates

- Expand and strengthen continuous and lifelong learning
- Coordinate policy on cross-border labor flows

Clearly, the role of skilled workers and their training is a vital part of the knowledge infrastructure that has to be upgraded continuously to fit the changes brought about by the emerging technologies and the increasing demand for their services as the economy adapts to new trends in business and technology.

Balancing the Deployment of Science, Technology, Engineering, and Mathematics Workers and Funds in the Regions

The dominance of the National Capital Region is evident in the deployment of researchers and funding in the administrative regions, as shown in Figure 4.5_1. R&D funding is, in turn, dependent on the presence of researchers in the regions. These disparities need to be addressed in the interest of inclusive development.

Increasing investments to develop and retain STEM talent in the regions should be accompanied by strengthening the regional innovation hubs, such as the Niche Centers in the Regions for Research and Development programs and the R&D infrastructure of HEIs in the regions (Ofreneo 2014).

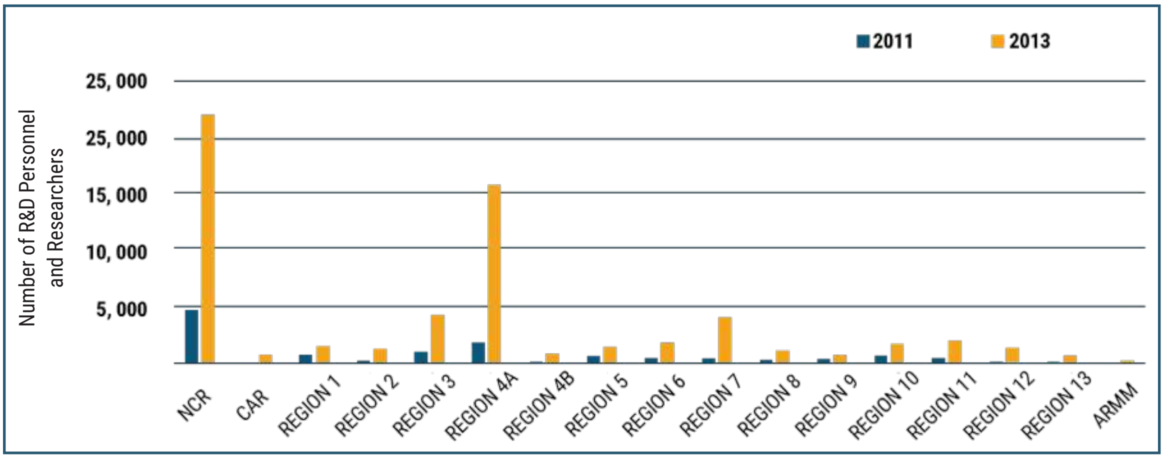


Figure 4.5_1. Number of R&D Personnel and Researchers in the Regions 2011 and 2013
Source: DOST (2015)

Attracting and Retaining Foreign/Filipino Science and Technology Professionals/ Practitioners

If we adopt only for discussion purposes the assumed UNESCO benchmark of 380 R&D personnel per million population, the DOST-Science Education Institute estimated in 2017 that the Philippines would need an additional 16,652 R&D personnel to meet the benchmark by 2022. This will require adding 3663 STEM graduates to the pool of R&D workforce every year.

In view of the intense global demand for talent in STI, the Philippines must adopt more vigorous measures to attract and retain Foreign/Filipino Science and Technology Professionals/Practitioners (FSTPs). Current efforts like the Balik-Scientist Program need to be supplemented by new initiatives based on the following principles:

- **Defined Relevant Roles and Responsibilities:** Allow active participation in national development by involvement in science-based policy formulation and decision-making.
- **Provide Resources:** Strengthen the R&D infrastructure of HEIs and design a more efficient and responsive supply chain for research materials and equipment by crafting a separate procurement guideline for academic and research institutions.
- **Recognition:** Confer honor and respect highly meritorious accomplishments of the STEM workforce by upholding the integrity of the merit system and inform the younger generation of these recognitions, so they can be inspired to pursue careers in STEM.
- **Compensation Package:** Provide compensation packages that can ensure a comfortable life for FSTPs and their families; facilitate relocation for those coming from abroad or from other regions in the Philippines.
- **Opportunities to Retool and Update:** Provide opportunities for regular retooling and updating in various fields of expertise by harnessing to the fullest the relevant provisions of RA 11448 (Transnational Higher Education Act) due to rapid developments in S&T. Conduct a study on how the emergent centers of scientific knowledge production in the Asia-Pacific have designed programs and policies to attract and retain scientific talent. As demand for scientific talent will be more competitive globally, it is important that a country which is not a “center” of scientific activity understands what it would take to compete for such talent and to keep them productive and happy.

Studies on professional development and migrant researchers point to a range of personal, professional, social, and cultural factors that influence global S&T researchers’ professional decisions on where to work and who to work with. (Ortiga et al. 2018, 2019). As the global market for scientific talent will be even more competitive in the coming decades, the Philippines should have a better understanding of the factors that make it a viable option for these talents, and the factors that might push these talents away.

Technologies to Enhance the Teaching-Learning Process

Current and emerging technologies are tools to empower teachers to become better users of instructional technologies such as case-based learning, collaborative learning, self-directed learning as well as sharing of views about concepts, and using diagnostics to monitor the effectiveness of the teaching-learning process (Dede 2014). Fullan and Scott (2014) characterized the "new pedagogy" to be one where there is easy and efficient access to information, wide use of digital technology and focused on real-life problem-solving.

There is renewed interest in revitalizing studies in Learning Engineering. The Institute of Electrical and Electronics Engineers (IEEE) defines learning engineering thus:

"Learning Engineering is a process and practice that applies the learning sciences using human-centered engineering design methodologies and data-informed decision making to support learners and their development." (IEEE, n.d.)

Learning engineers integrate engineering and systems thinking to provide support for the development of new technologies for learning to maximize its value. Learning engineers use their knowledge in pedagogy and technology to put together and evaluate a whole teaching-learning environment.

The current COVID-19 pandemic highlights the severe inequalities among regions in the country as regards the infrastructure for digital education. Our IT infrastructure is poorly distributed and poses severe limitations to access good quality STEM education now and in the future. Viable long-term solutions to these inequalities should consider technologies and sound policies.

According to Dede (2014), new technology infrastructures are needed to facilitate access to instructional materials globally and enhance the continuity of the learning. Thus, acquiring digital skills will be the default for all Grade 12 and college graduates (Dede 2014). Large scale disruptive events like the COVID-19 pandemic have made it even more necessary for these skills to be learned.

Dede (2014) has suggested that the following technology infrastructures be established:

- **Digital teaching platform:** A teacher-led classroom infrastructure as the primary instructional environment to implement the curriculum, personalize instruction, and promote knowledge integration and collaborative learning. An example would be the Learning Management System.

- **Immersive Authentic Simulations:** This refers to the virtual environment to enable the student to obtain a realistic experience even if one is not physically located in a place. This includes multiuser virtual environments and augmented reality, where students interact via mobile wireless devices with simulations and other virtual information and visualization. An example is the flight simulator used to train pilots.

Brown et al. (2015) describe the features of a next generation digital learning environment as “interoperability, personalization, analytics, advising and learning assessment, collaboration, accessibility, and universal design.” These features can be put together in various ways to suit preferred individual and institutional learning environments.

The teacher and the student must have access to gadgets such as personal computers or laptops or tablets or smartphones as well as access to broadband connectivity. Otherwise, radio and TV networks may be used as tools for instruction. Until access to these gadgets and bandwidth is universal, a blended approach may have to be adopted in resource-poor communities. Nevertheless, facilities to produce materials for print or broadcast must be available such as high-capacity printers, binders, and quality production facilities for radio and TV. Another concern will be the distribution of both printed and broadcasted materials especially in island communities. Hard to reach places may access satellite-based communications, but these tend to be expensive.

The challenge in the deployment of digital technologies is access to broadband connectivity. This problem is quite common in developing countries where access to power and connectivity is limited. Thus, the International Telecommunications Union conducted a study on “Broadband development and connectivity solutions for rural and remote areas” (ITU 2019) and provides the following technological measures, also mentioned in Section 4.4, that are currently used for last mile connectivity:

- wired systems including optical fiber: high information capacity
- traditional wired local area networks: copper coaxial cables modified to support higher transmission bandwidth and improved modulation
- cable TV systems: bi-directional communication, limited user capacity
- optical fiber: high capacity, high performance, low error rates
- WiFi technology: hot spots and local area networks can be installed at points of community activities. Backbone landing should not be far from the locality.
- high-altitude platform systems and unmanned aerial vehicles (UAVs) such as drones, can serve as mobile base stations to provide connectivity.

Given the above challenges in the production, distribution, and use of digital instructional materials, software-defined networking will be a vital tool to enable a programmatically efficient network to operate. Such networks have to be flexible and agile and able to manage traffic from a centralized console.

Conclusion

Recent reports on the performance of fifth grade students that are falling behind their peers in some ASEAN countries as indicated by data from the Southeast Asia Primary Learning Metrics (UNICEF and SEAMEO 2020) as well as the low ranking of the fourth-grade students in math and science in the Trends in International Mathematics and Science Study (Mullis et al. 2020) makes it imperative to conduct an overhaul of our STEM programs in K-12 because of concerns on the quality of the feeders to undergraduate and graduate programs in STEM.

Earlier, the poor quality of instruction in HEIs was mentioned. Recent newspaper reports also indicate the need for improvement of TESDA training programs.

Our dismal standing in these international tests has been known for at least two decades now. A serious effort to improve our ranking must now receive priority support. Tools and materials are now available to enable our STEM educational system to reform and upgrade.

SECTION 4.6
FOOD SECURITY AND NUTRITION

Agricultural Production, Post-Production, and their Natural Resource Base

By 2050, the agriculture sector will continue to play a critical role in achieving the Philippines' national development targets considering its natural terrestrial, marine and aquatic resources. However, the characteristics and scale of the Philippines' agricultural production and post-production systems will be significantly different compared to the present, due to the country's evolving political and economic development path, socio-demographic composition, human capital priorities, types of technological systems, decreasing agricultural land, biophysical condition of the agricultural systems, and climate change.

While the agriculture sector remains a key player in the Philippine economy, its full potential has not been fully maximized due to the combination of economically volatile exports and productivity losses caused by weather extremes, and poor utilization of modern technology, among a myriad of factors.

Philippine agriculture has continued to lag behind Southeast Asian neighbors in terms of productivity growth, technological inputs, and the perennial lows of its capital investments have greatly reduced its competitiveness in the region.

The sluggish growth in agriculture through the years—from an annual average of 4% in 1970s to about 3% in 2000s to 2010s—is largely due to the significant decline in the average gross value added (GVA) growth rate of crops, from 6.8% in the 1970s to about 3% in the early 2000s and up to the present.

The share of agriculture in the national economy has been stagnant at 11%-12%, in contrast to the services and manufacturing sectors.

The evolving context of agriculture, rural development, and the status of farmers in the Philippines is also affected by the socio-economic and political climate not just within the Southeast Asian region but also across the globe. The prevalence of poverty is highest in the rural areas and the fishing communities.

It is envisioned that a strengthened economic cooperation between the Philippines and the world through more competitive market and trading systems would usher in knowledge and human capital exchange, farm production and post-production management, intervention knowledge base, and more accessible and efficient flows of goods and services. However, much of this would depend on how the Philippines would be effective in aligning its current national priorities with the rest of the world, as the country needs to revitalize its agriculture sector around these regional and global priorities to realize its full impact to the Filipino farmers.

In the future, the continuing importance of the agriculture sector in a maritime and archipelagic Philippines, will provide a strong impetus for maximizing its potential for reducing poverty, achieving food and nutrition security, protecting the environment and providing ecological services—both in the rural and urban sectors.

According to 2015–2019 estimates, 36 million people in the region live below the international poverty line. With the average nominal gross domestic product (GDP) per capita of USD 4,755 as of 2019, the agriculture sector is seen to be in a strategic position to further close the gap in the seemingly increasing income inequality in Southeast Asia, averaging at a Gini coefficient of 77.23.

While Asia had an estimated 81.7 million undernourished people in 2019—many of whom are women and people living in marginal areas who are most vulnerable to food insecurity—about 57.9 million malnourished individuals are from the Southeast Asian region (UNICEF, WHO, and World Bank, 2019). Clearly, agriculture must not just be positioned for increased food production, but also in its ability to improve the nutritional status of the population. The food system paradigm can make this aspiration a reality.

Food Security and Nutrition Challenges

The food system refers to the chain of human activities that cover food production, post-production, marketing, consumption, and waste management. Aggregately, these components constitute the single most important driver of the mega problems facing the country today: resource depletion, population growth, pollution, climate change, malnutrition, inequality, and poverty. The existing food system in the Philippines has been dysfunctional for many years. and it is bound to become worse if not corrected.

Sustainable food systems, according to the Food and Agriculture Organization of the United Nations (FAO), should have green growth, inclusive growth, and eco-social progress, where the latter suggests a link between sociology and the environment. Past approaches have focused narrowly on food production, while the FAO's higher order approach identifies the challenges of creating more balanced and holistic policies and programs to achieve the desired nutritional outcomes. For example, a policy that promotes nutrition-sensitive agriculture (more diverse) will have a significant impact on the food system. This will deliver broad-based benefits to society and have a positive or neutral impact on the natural environment. Resilience is another feature of sustainable food systems, given the multiple risks.

The Philippines is off course in meeting the global targets for all indicators analyzed with adequate data (Global Nutrition Report 2020). According to the 2018 Expanded National Nutrition Survey (ENNS), nutrition problems besetting the country include stunting, overweight across all age groups, and anemia among women of reproductive age, among other indicators (DOST-FNRI 2020).

Filipino children are increasingly suffering from poor diets, inadequate nutrition and food systems that are failing them (UNICEF 2019). "The undernutrition facts in the Philippines are disturbing—one in three 12-23-month-old children suffer from anemia while one in three children are irreversibly stunted by the age of 2. One (1) in 10 adolescents are obese from wrong eating habits," said Oyun Dendevnorov, UNICEF Philippines Representative. "The triple burden of undernutrition, hidden hunger and overweight poses serious threats to child health." Adolescent obesity among Filipinos has almost tripled in the last 15 years (DOST-FNRI 2020) as processed foods high in salt, fats and sugar are becoming more accessible and affordable. Adolescents are eating unhealthily diets, which are not meeting their nutritional needs.

Indeed, the Philippines is still suffering a malnutrition burden. As of 2015, the national prevalence of overweight among children below five years of age is 3.9%, which has decreased slightly from 5% in 2013. The national prevalence of under-five stunting is 33.4%, which is greater than the developing country average of 25% (DOST-FNRI 2016).

Conversely, the Philippines' under-five wasting prevalence of 7.1% is less than the developing country average of 8.9%. In the Philippines, 33% of infants under six (6) months are exclusively breastfed. The Philippines' low birth weight prevalence of 20.1% in 2015 has decreased slightly from 21.5% in 2000. The Philippines' adult population likewise faces a malnutrition burden: 15.7% of women of reproductive age have anemia, and 7.3% of adult women have diabetes, compared to 7.1% of men. Meanwhile, 7.5% of women and 5.2% of men are obese (Global Nutrition Report 2020).

Poverty and Inequality, as Causes of Malnutrition

Malnutrition is caused by interrelated factors including health as well as physical, social, economic and other conditions. Poverty is the main root of malnutrition and is the particular cause of inadequate food intake. Slow economic growth in the 1990s and 2000s, coupled with stagnant inequality (see Gini index, Section 3.2), led to a caesura in the eradication of poverty and persistent malnutrition (Briones et al. 2017).

The percentage of food-secure households—here, food security is defined as being able to eat three full meals a day, or at least not going to bed hungry—decreased from 51.3% in 2013 to 36.1% in 2015, while the percentage of food-insecure households increased from 9.5% in 2013 to 29.2% in 2015 (Silva, 2018). In 2014, the Philippines' Global Hunger Index (GHI) score—based on three indicators: undernourishment, child underweight, and child mortality—was 13.1. The ideal score, indicating low hunger, should be below 5. Our country thus ranked 29th in the world in terms of hunger, with its situation categorized as a "serious problem".

Over the past 15 years (1999–2014), the number of Filipino families who rated themselves as hungry based on the Social Weather Station's self-rated hunger survey rose from 8.3% to 18.3% (Focus on the Global South-Philippines 2014). Under the COVID-19 pandemic, the number of hungry Filipinos doubled due to the COVID-19 lockdowns (SWS 2020a).

The most important underlying cause of hunger during the pandemic is the inaccessibility to food due to lack of income, as millions of people lost their jobs.

Food Supply, Markets, and Nutrition

Food supply, and how it is distributed and consumed by the populace, has a consequent impact on nutritional status. Studies reveal that many Filipinos suffer from lack of food or poor diets, despite rising food availability and greater food supply. High-priced rice hurts Filipino consumers, especially the poor, because it is a staple food item. Rice accounts for more than a third (33% in 2012) of the total food expenditure of the bottom quintile; the single biggest source of energy and protein at 34% compared to fish (14%), pork (9%), and poultry (6%); and the biggest contributor to per-capita availability of calories at 46% compared to sugar (8%), wheat (7%), and pork (7%).

The bulk of Filipinos' food consumption goes to cereals, followed by meat and fish; per capita consumption of vegetables only averages 22 kg per year, compared to the FAO recommendation of 146-182 kg per year (Briones et al. 2017). This results in high deficiencies of vitamins in the diet.

Poverty is the fundamental cause of malnutrition and is seen as the main hindrance to a healthy diet. The future food system transformation that is going to take place in 2050 and beyond will revitalize the economy, as this will spur employment (both self-employment and wage employment). Its holistic nature will allow employment to extend far beyond farm production to include a wide range of activities, including food processing, transportation, and retail. And, as incomes rise, local demand for and spending patterns on food will change. The overall share of expenditure on food continues to rise, but the shares of those increases spent on cereal decline relative the share spent on fresh, processed, and convenience foods (IFPRI 2018).

The changing dietary patterns and food demand in the cities will drive the shift in agriculture from a monoculture cereal, or industrial production, to more diversified, or artisanal, production in rural areas. Urban agriculture will also be popular.

Impacts of Climate Change on Production and Yields in the Philippines

A study by Perez and Rosegrant (2019) assessed the direct impacts of climate change on agriculture, which affects crop productivity as a result of heat and water stress (IPCC 2014).

Studies project that by 2050, the world's total agricultural crop yields may fall by 4.5% on average, compared with baseline levels reflecting no climate change as shown in Figure 4.6_1.

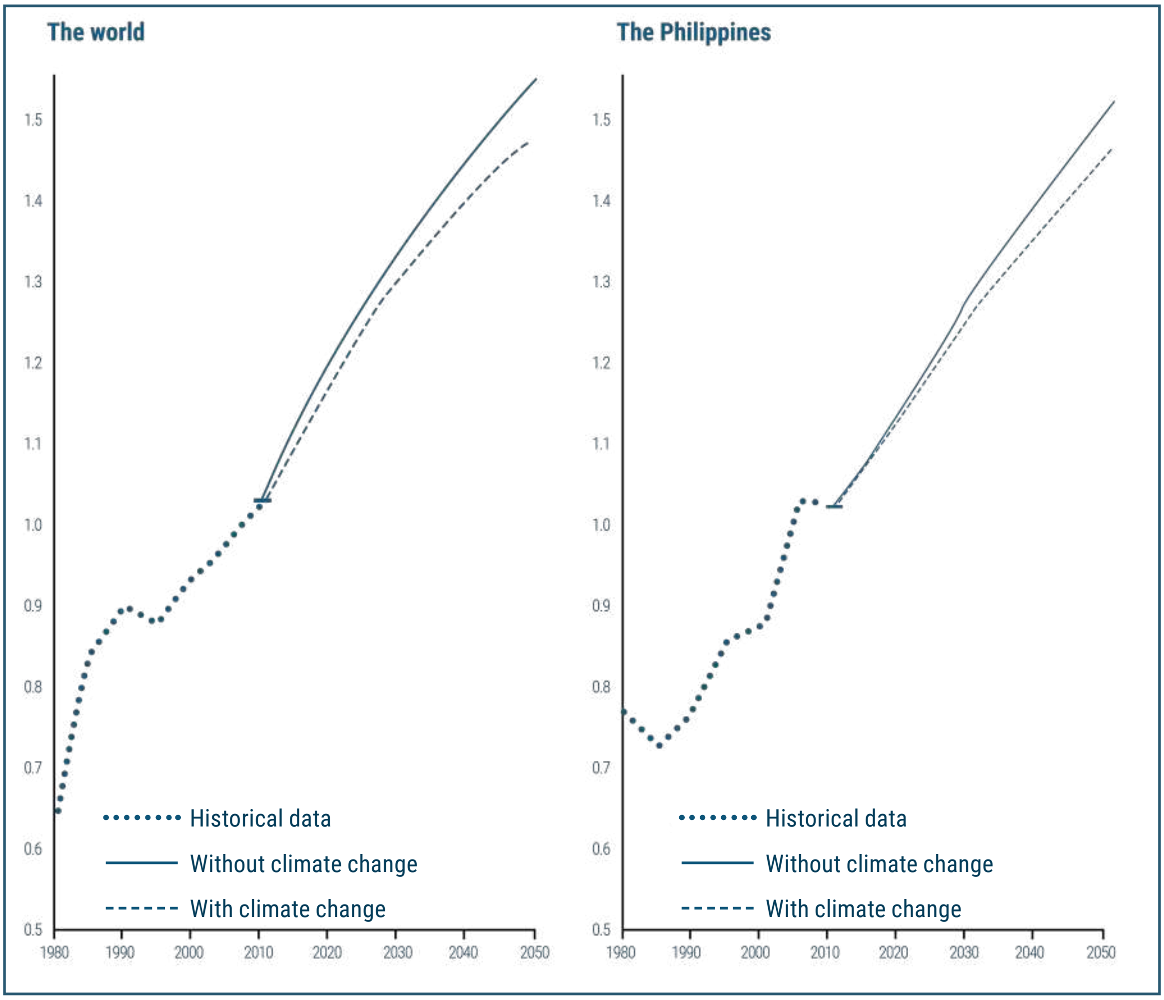


Figure 4.6_1. Historical and Average Projected Agricultural Crop Yields, with and without Climate Change, 1970–2050
Source: Perez and Rosegrant (2019)
Note: Data are based on average values from the four climate models underlying the analyses

In the Philippines, Perez and Rosegrant (2019) projected that climate change will cause yields to fall by 2.9%, on average, with positive yield effect on fruit and vegetables, pulses, and roots and tubers. For rice and corn, the negative yield impacts are lower for the Philippines than for the rest of the world, at 4.1% and 7.7% for rice, respectively, and 15.7% and 18.8% for corn, respectively (Table 4.6_1).

Given the extensive cultivation of cereals (in this case, rice and corn), sugarcane (accounting for more than 50% of agricultural land), tree crops (such as coconuts, and fruit and nut trees), and perennials (such as bananas and coffee), overall Philippine production is projected to decline by 1.7% owing to climate change, despite positive average impacts on all other crops (Table 4.6_1).

Cereal production is projected to decline by 6.1% by 2050 in comparison with baseline levels, whereas fruit and vegetable production is projected to rise by 3.9%. These results further emphasize the lower contraction in the production of rice and corn in the Philippines, compared with the rest of the world (Table 4.6_1).

Table 4.6_1. Average Projected Impact of Climate Change on Agriculture Globally and in the Philippines, 2030 and 2050

Impact of Climate Change	The World		Philippines	
	2030	2050	2030	2050
	Change from Baseline Levels (%)			
Crop yields				
All crops	-2.4	-4.5	-1.7	-2.9
Cereals	-3.7	-6.9	-3.7	-7.6
Corn	-10.4	-18.8	-7.6	-15.7
Rice	-4.2	-7.7	-1.7	-4.1
Fruit and vegetables	-0.3	-0.0	1.4	1.9
Pulses	-1.2	-1.9	0.3	0.7
Roots and tubers	-1.5	-2.6	0.0	0.2
Sugarcane	-5.8	-11.2	-4.1	-8.3
Crop production				
All Crops	-1.9	-3.4	-1.0	-1.7
Cereals	-3.4	-6.0	-2.3	-6.1
Corn	-8.3	-17.0	-5.8	-13.0
Rice	-2.9	-5.5	-0.6	-3.2
Fruit and vegetables	-0.8	-1.7	2.0	3.9
Pulses	-1.3	-2.4	-0.3	0.5
Roots and tubers	-1.7	-2.9	-0.5	-0.5
Sugarcane	-1.7	-3.2	-1.8	-3.0
World/consumer prices				
Cereals	10.6	23.9	14.0	24.3
Corn	22.7	44.4	22.7	44.4
Rice	12.0	25.7	12.0	17.2
Wheat	2.3	11.1	2.3	11.1

Table 4.6_1. Continued

Impact of Climate Change	The World		Philippines	
	2030	2050	2030	2050
	Change from Baseline Levels (%)			
Fruit and vegetables	4.5	9.6	6.1	12.7
Pulses	6.0	12.0	6.0	11.6
Roots and tubers	4.2	8.3	2.5	5.8
Sugar	3.9	7.5	3.9	7.5
Consumption				
Cereals	-1.8	-4.2	-2.0	-3.1
Corn, as food	-4.9	-8.62	-3.2	-5.6
Corn, as feed	-10.6	-21.48	-8.7	-18.2
Rice	-2.7	-5.41	-2.2	-2.9
Wheat	-0.6	-2.77	-0.7	-3.4
Fruit and vegetables	-0.8	-1.67	-1.2	-2.3
Pulses	-0.7	-1.27	-0.2	-0.4
Roots and tubers	-1.5	-2.49	-0.5	-0.9
Sugar	-1.1	-2.05	-1.3	-2.4

Source: Perez and Rosegrant (2019)

Note: Data compare average results of climate change simulations from the four general circulation models underlying the analyses in this chapter with baseline results under a scenario of no climate change.

Towards a Transformed Agricultural Food Systems

Philippine commercial agriculture requires a massive systemic transformation toward sustainability. As the country's agriculture has continued to expand and intensify, its wide-ranging negative externalities have taken toll on the very resource base that supports its productivity.

Across the country, environmental degradation has been rampant, as various natural areas were planted to high-value crops of high demand in the international markets. Major challenges in Philippine agriculture include: deforestation, soil erosion and degradation, greenhouse gas emissions, mangrove ecosystems degradation and water and air pollution, among others. Environmental challenges clearly drive the need for green agriculture in the country.

The aim of transforming Philippine agriculture toward sustainability is founded on our aspirations of achieving a genuine green agriculture sector for the country. However, a closer look of the current policies indicates that the Philippine government has just started to formulate policies that embody the elements of green agriculture.

The initial seeds of applications of green agriculture can be observed in a number of direct regulations, and through a number of market instruments applied to the agriculture sector of the Philippines.

These were promulgated in the Philippine Development Plan and in the Organic Agriculture Act of 2010 (RA 10068) that provide regulatory mechanisms related to green agriculture. Also related to this are a number of specific instruments that correct and create markets, such as the Philippine Good Agriculture Practices (PhilGAP), Environmental Users' Fee system, environmental accounting, and payments for watershed protected and conservation, among other interventions.

Unfortunately, more significant gains from these interventions have yet to be felt, especially since these are currently implemented only sporadically.

The traditional view of the food system is that it is linear, with three sequential steps: production, marketing, and consumption. This kind of system will not sustain us to 2050. We need additional components, post-production and waste management, and make the system circular with responsible consumption at its core. The traditional way of fixing the system is to work on the production side, which explains why we always view the problem as a problem for the Department of Agriculture.

Occasionally, marketing is the problem: when traders deliberately manipulate supply, prices go up, and consumers complain. We never looked at the consumer as part of the problem. The consumer, to our mind, is always the victim.

The reality is that the consumer is at the core of the system. When we choose to eat white rice, for example, the farmer responds by producing the grain and the millers respond by removing most of the nutrients from the grain to produce the white rice. The retailer delivers it to us in plastic bags.

As a consequence, we suffer because excessive white rice consumption is linked to chronic diseases (Liang et al. 2010; Hu et al. 2012; van Dam et al. 2020). Environment suffers from the extravagant use of water and land resources, pollution in the rice farms as well as from plastics used in marketing. Ironically, the farmer also suffers because there is not enough money from growing rice to meet the family's basic needs.

Imagine what will happen if the consumers change their food habits and decide to eat brown rice, and less rice, but more mungbean (Figure 4.6_2). These will encourage the rice farmer to include mungbean in his farming system, earn more, and spend less on fertilizer for rice, because mungbean can supply some of the soil nutrients.

Consequently, pollution will be reduced, because about half of the chemical fertilizers applied to rice are not used by the plant, and end up as pollutants. Furthermore, the miller will produce brown rice, with a 10% higher milling recovery, solving our perennial problem of shortage (note that we import about 10% of our rice requirement every year). Other spillover effects could be the pressure from the consumer to use biodegradable packaging materials such as the bayong, instead of plastics. Such as shift could revive the use local packaging materials derived from bamboo, palm and banana leaves. With more nutritious brown rice being consumed daily, the population will be expected to be healthier.

This analysis shows that consumer behavior ultimately determines the outcome and impact of the food system. Therefore, we propose a change in consumer behavior as a starting point for fixing our dysfunctional food system (Figure 4.6_2).

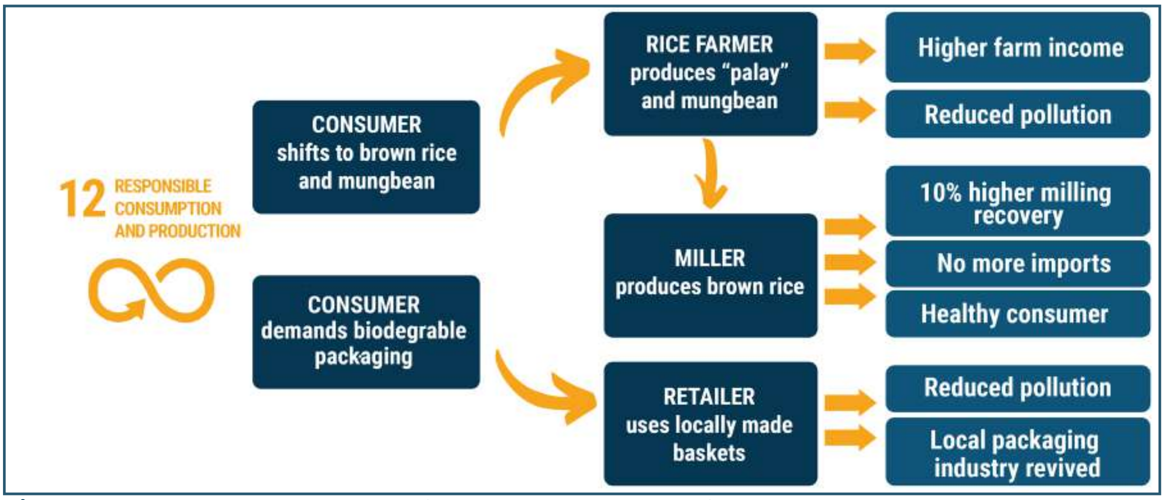


Figure 4.6_2. Consequences of Consumer Choice of Food and Packaging.

Socio-Technological Innovations for the Agriculture Sector

Overall, there is clearly a wide gap between the aspirations and applications of sustainable agricultural technologies in the Philippines that would significantly improve productivity and social impact.

The major contributing factors to this limitation include the inefficient regulatory application on land use and environment management policies, lack of environment financing, and the lack of knowledge and skills to mitigate environmental risks from agriculture. In terms of policy direction, the country needs to fully realize that changing the position of its agriculture sector from being purely extractive in nature to green agriculture is possible.

While rather slow, the transformation of agriculture in the Philippines is gradually taking form by addressing various environmental risks and impacts from agriculture. Such slow-paced development could be related to challenges in coordination, trust and funding—as has been pointed out by key players, such as the local governments and the private sector.

For local government units, the need to fully decentralize policies would be instrumental in allowing them to play active leadership in agriculture. For the private sector, their initiatives for improving overall environmental performance have become the norm in response to international standards and markets, and they would need substantial support from the government to fully sustain their momentum.

This can be done by increasing government focus on technology transfers and skills development to further mitigate environmental degradation—such as accrediting certifying bodies, providing training and information for farmers on technologies that would reduce risks from commercial agriculture, and promoting good agricultural practice including organic agriculture and farm diversification.

Other methods will require mainstreaming of environmental regulations in local government unit (LGU) development plans, prioritizing environmental risk mitigation in government development programs and investment plans, efficient monitoring and evaluation of regulatory measures like banning of aerial spraying, measuring low carbon emissions, and creating a biodiversity index. Such measures can be implemented at the national level.

Figure 4.6_3 below shows a listing of proposed priority areas for research and technologies in agriculture and allied fields to accelerate the transformation of the agriculture sector and strengthen its contribution to socio-economic development—particularly toward resilience against pandemics.

State universities and colleges are expected to pursue academic and research programs that accelerate the science and art of agriculture toward economic development. Agricultural research themes and modalities have been put in place such that higher education institutions (HEIs) can re-orient their research and development programs from a business perspective towards systemic change of the agriculture sector.

Food Security Pillars

Levels of Analysis	Availability	Accessibility	Stability	Utilization	Modalities
Biosphere	• Local and international trading system • (National) Food reserves • GIS and remote sensing, Artificial intelligence • Big data system • Commercial and Industrial farming	• Transport and logistic system • Use of online platform and internet-based solution • Automated weather stations and systems • Land conversion and optimization • Biofuels	• Financial technologies • Environmental risks and management • Weater-index based agricultural insurance	• Transboundary food quality standards • Trande regulation and standards • Circular economy • Registration and certifcation systems	Transdisciplinal
Ecosystem/Landscape	• Organic and traditional farming • Controlled environment framing (i.e., soil-less agriculture, hydro- and aqua- ponics, vertical farming • Urban agriculture • Precision farming • Conservation agriculture • Integrated pest management • Zoonotic diseases management • Plant biomass (i.e., straw) management • Animal waste management	• Good Agricultural Practices (GAP) • Crop insurance system • Integerate-on-farm value adding • ICT-based farming • Efficient irrigation system • Industrial farming • Cold storage facilities • Post harvest technologies • Waste management (i.e., food waste)	• Risk Communication • Agricultural policies and regulations • Environmental governance	• Responsible consumption behavior promotion • Food quality and safety • Food technology for health and wellness • Product traceablity	Interdisciplinal
Population/Communities	• Pest and disease management • Plants and soil nutrient management • Post-harvest management • Participatory varietal selection • Biotic and abiotic crop tolerant varieties • School, home, and community gardens land use policies • Sustainable animal and fish nutrition • Nutrient-enrichment of food	• Digital farms • High-pressure, hydraulic system • High-speed, high precision equipment • Hyroponics/ aquaponics • Remote sensing	• Community bio-efficacy trial • Weather variability and forecasting • Price fluctuations and economic factors of production	• Food quality and safety • Food technology for health and wellness • Food sensory evaluation • Food processing • Halal awareness and standards	Multidisciplinal
Genes, Cells, Organisms	• Molecular assisted breeding • Nanotechnology • Transgenic technology • Biotechnology	• Genetic breeding • Hologenome selection • High-throughout phenotyping • Tissue culture/embryo rescue • Bioinformatics • CRISPR-CAS Medical trials	• Genes insertion stability	• Bioefficacy and bioavailability of novel products • Food safety • Pesticide use and regulations	Disciplinal
	Farmer/ Producers	Processor/ Manufacturing	Distributor/ Retailer	Consumer	

Components of the Food System

Figure 4.6_3. Examples of Proposed Key Priority Areas for Research and Technologies in Agriculture

Transformation in the Filipino Diet

The Planetary Health Diet (PHD) is a general guide that is sufficiently flexible for application to local conditions, down to the provincial level. It differs from traditional guides such as *Pinggang Pinoy* in that the impact of consumption on the environment is factored in. The difference between our existing diet and the PHD is in diversity, best seen in the colorful plates of the PHD (Figure 4.6_4). On the other hand, the typical diet is dominated by white rice. If the diversity is duplicated in the farms, farmers are expected to benefit by having a more sustainable farming environment and higher income This would address the third concern of the food system: the farmer. (The first two concerns are consumer health and nutrition, and environmental health.)

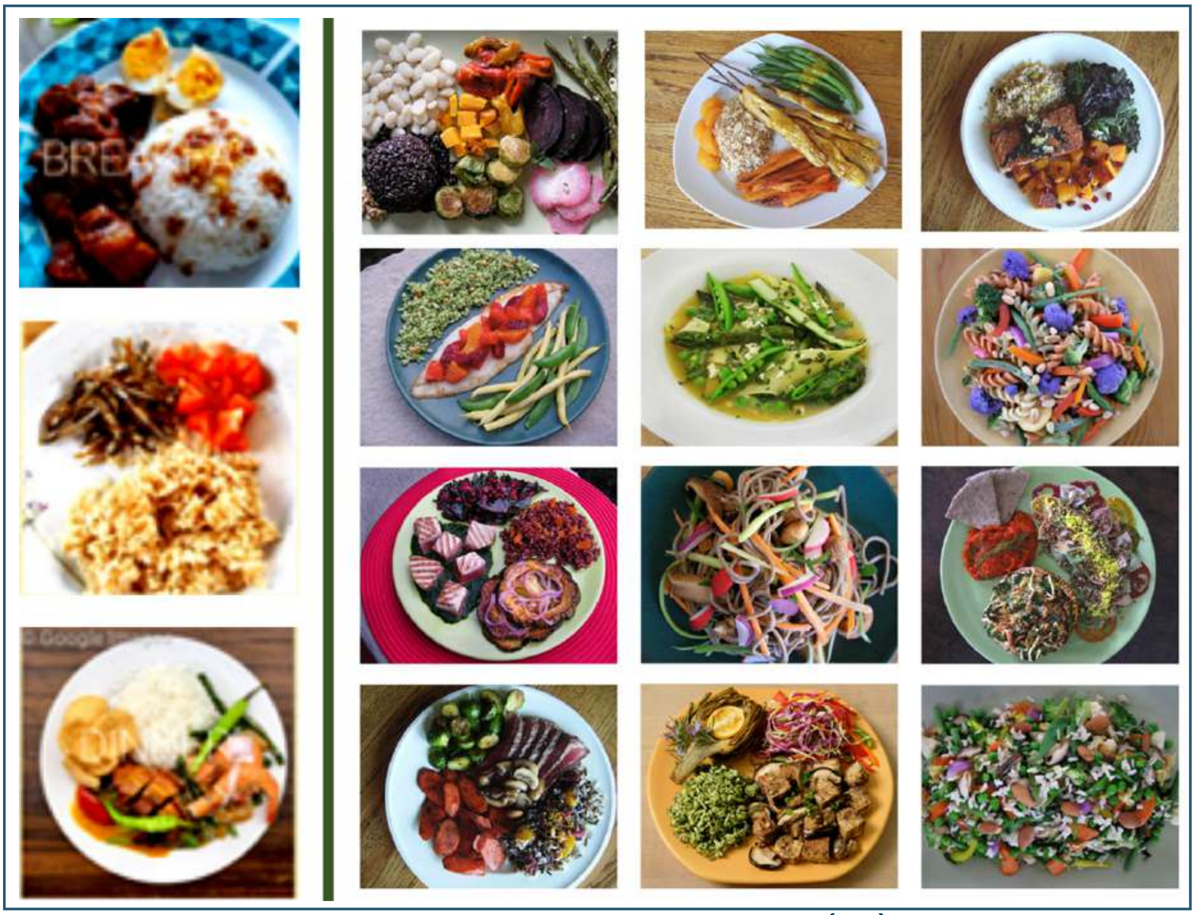


Figure 4.6_4. Comparison Between the Typical Filipino Diet (left) and Different Versions of the Planetary Health Diet (right)
Source: EAT (2019)

In the context of the Philippines, adhering to the PHD will drastically change the food consumption pattern, and ultimately, the structure of farming. For example, the 36% reduction in rice consumption mandated by the PHD may reshape the Philippine agricultural landscape. It may free up as much as 1.5 million ha of prime agricultural land for more nutritious, more profitable, and environment-friendly crops.

If rice is replaced by mungbean, which is needed in large quantities, the environment will benefit because mungbean production produces less greenhouse gases and uses less water than rice. If these available rice areas are grown to high-value vegetables, which command higher prices, it will increase farmers' incomes, enhance participation of women and children in farming, and increase the supply of affordable and nutritious food in the farm family and other consumers.

Growing high-value vegetables and fruits through an environment-friendly production system will help reduce GHG emission and preservation of human health and natural resources. Farmers seeking to diversify rice production of rice areas into production of other high-value crops may be funded by tariff collections from rice imports exceeding PHP10 billion under Article 13, Section 13 (Rice Competitiveness Enhancement Fund) of RA 11203, or rice trade liberalization law.

Changing eating habits will not be easy and may not be initiated by giving the children a more nutritious and varied diet at a young age, one rich in vegetables and fruits, and by educating these children about the health benefits of such a diet. Improving the nutritional condition and dietary habits of school-aged children by increasing and enabling year-round production of locally adapted and highly nutritious vegetables and fruits through school and home gardening may contribute to improving academic performance of school children, alleviating hunger, and securing their family's food and nutrition.

This is why we plan for a 30-year sustained effort. The middle class is educated, and more willing to experiment with food choices. The basic change we aim for is the change in the food selection criteria from the present (based on price, convenience, and taste) to one that will be driven by data and values.

For this, the consumer may need help from a modern tool for data- and values-driven food buying that gives food recommendations based on genomic data. The idea is for the consumers to submit their genomic information, which will be analyzed followed by advice on what food to eat and what food to avoid. This system can be improved by using other data, like the PHD recommendations and their budgets, and values that may involve concern for the local farmer, animal welfare, and religion. We can tentatively call this PHD Plus App, and use the smartphone as a platform to guide grocery shopping or ordering food from a cloud kitchen (Rasco 2020).

Key features differentiating the envisioned 2050 food system from the existing system to be adapted to the maritime and archipelagic features of the Philippines are as follows:

1. **Individual consumption decisions will be data- and values-driven.** Biological needs, financial capability, concern for the farmer and the environment, and preferences dictated by religion and tradition will be factored in. The envisioned PHD Plus App will assist food shopping. Prepared food supplied by "cloud kitchens"—i.e., shared commercial facilities purpose-built for food delivery—will be the norm.

2. Connection between food producers and the consumer will be more direct. There will be multiple channels: among these are farmers' markets, food terminals, and direct delivery from farm to household or food service providers.

3. Food production will be highly diversified, local, and seasonal. This will provide food security against disruptions caused by calamities, and provide additional income for local farmers.

4. Production will be closer to the kitchen, as urban and peri-urban farms get a bigger share of the food market. Controlled environment farming (i.e., soil-less agriculture, hydro- and aqua-ponics, and vertical farming) is the necessary innovation, as land and water resources for traditional farms are finite. It is an added assurance of food security, amid environmental concerns.

5. Food production from the aquatic environment will grow faster than land-based production. The aquatic resources around Metro Manila are extensive, with Manila Bay, Laguna de Bay, and Taal Lake. In contrast, agricultural lands are being converted to other uses.

6. The food system will be circular. Material and energy will be recovered from waste, valued as a resource, and returned to the farms and households. The result will be cleaner cities and reduced external inputs in food production.

7. Steps in the food system will be inter-connected, allowing for a high-level of transparency and efficiency. Farmers and consumers will have more market power.

8. Reduced postharvest losses with adequate dryer and cold chain. This is also an added assurance that farmers will not be pressured to sell cereal crops with high moisture contents and a perishable product at a low price.

9. A revived industry based on the use of biodegradable materials for food packaging. This is a game-changer for creating a new industry and reducing pollution from the food system.

SECTION 4.7
HEALTH SYSTEMS

Our population age structure is relatively young as of 2020, with a fertility rate that will likely maintain a well-sized working-age population, our fastest-growing age group is over 60 years. By 2050, the Philippine population is likely to have a larger proportion of older people (Reyes et al. 2019).

With adequate human development, the future population that is nurtured towards high societal and economic quality can be an asset. Only with good health enabling productivity can the potential of Filipino human capital be harnessed. Even paradigms—such as the fourth industrial revolution—are premised on maximizing health throughout the life-course, since productivity among the elderly is prepared in the decades prior to old age.

The population is, officially, over 50% urbanized in terms of residence as of 2015, though the definition of "urban" also factors into this statistic (PSA 2019c). Regardless, mental health and chronic illness trends are compatible with some degree of leapfrogging into "diseases of modernization and urbanization", even as "old" public health problems persist: tuberculosis, malaria, and neglected tropical diseases, also known as "diseases of poverty". Ironically, we are one of the top promising economies globally, which would only accelerate the transition toward so-called lifestyle diseases and, soon enough, ailments of longevity—an uptrend that has already begun.

The most vexing layer of the problem of population health is that of inequity in health—a social divide that worsens the picture regardless of what the health issue might be. Gaps exist between socioeconomic groups, so their contexts, health issues, and necessary solutions vary in material ways. As intrinsically undesirable as inequity is, it also adds to the breadth of health issues we face, which stretches our responses thin.

The country's health systems did not grow or develop at pace with the country's population. The evidence of stagnation is varied, and conspicuous, most poignantly by the historically high proportion of Filipino deaths going unattended by a health professional.

To be fair, local champions of health have not been silent, following each attempt at health reform with another, sometimes using various approaches, and sometimes iterating on the same critical ones. The latest of these is the Universal Health Care (UHC) Act, an ambitious law that, while not perfect, may at least be said to have learned from the past. Its success will ultimately depend on excellence in implementation.

It was also fitting to have an almost experimental setup of UHC implementation, when the UHC Integration Sites were recognized (DOH 2019). There were criteria to fulfil before it could be considered "integrated", and there is national government assistance on offer for integration activities by serious contenders. By espousing a vision through the Act, defining its framework and outcomes, implementing provinces and cities were allowed to devise the most appropriate solutions and methods from which the rest of the country can learn.

Within the health sector, it was in this pre-implementation context of UHC that this 30-year Foresight was commissioned. Thus, Foresight positions the health science, technology, and innovation (STI) areas in the role of supercharging the UHC sites' integration processes, using STIs as tools, and developing them further for the express purpose of accelerating the pursuit of UHC.

However, the COVID-19 pandemic struck the Philippines just as the Foresight project was taking off, and it taught valuable lessons that highlight the very problems the UHC Act and its predecessor reforms sought to address. This pandemic exposed the vulnerabilities of the health system to such emergencies. Public health crises highlight and intensify existing problems more than they create novel ones.

The Vision: Universal Health Care as Starting Point for the Foresight

In light of the well-known challenges for health in the Philippines, UHC as an agenda, and as embodied in RA 11223, was seen as a worthwhile goal. This agenda unpacks the health future envisioned in the national development plan, AmBisyon Natin 2040, to acknowledge the challenges when pursuing the health aspects of the Philippine Development Plan. It also organizes a set of responses to these challenges, in domains of reform cascading from the structural and policy levels down to the operational front lines of care, now backed by the law.

The Universal Health Care Act is a unifying framework for all UHC-related pursuits in the country after 2019. UHC is not unique to the Philippines. It is a global goal for health. It is well established in the literature that several key areas are generally regarded as intrinsic, or instrumental, to the attainment of the right to health care for all people. This is distinct from, but inclusive of, universal health coverage, in which the defining features of success are that health care is financially accessible to those who need it, when they need it; and that it does not impoverish those who use it.

UHC figured early in the health foresight process by defining the central problem as unequal access to health care (Figure 4.7_1). From the Problem Tree, we identified four main axes of factors driving the problem, namely:

(1) patient-side health literacy governing how or whether they access care
(2) quantity, distribution, and quality of health facilities
(3) health financing alongside affordability of care
(4) health workforce concerns

Insufficient budget and resource allocation was determined as a major concern as it was connected to three of the four main axes identified.

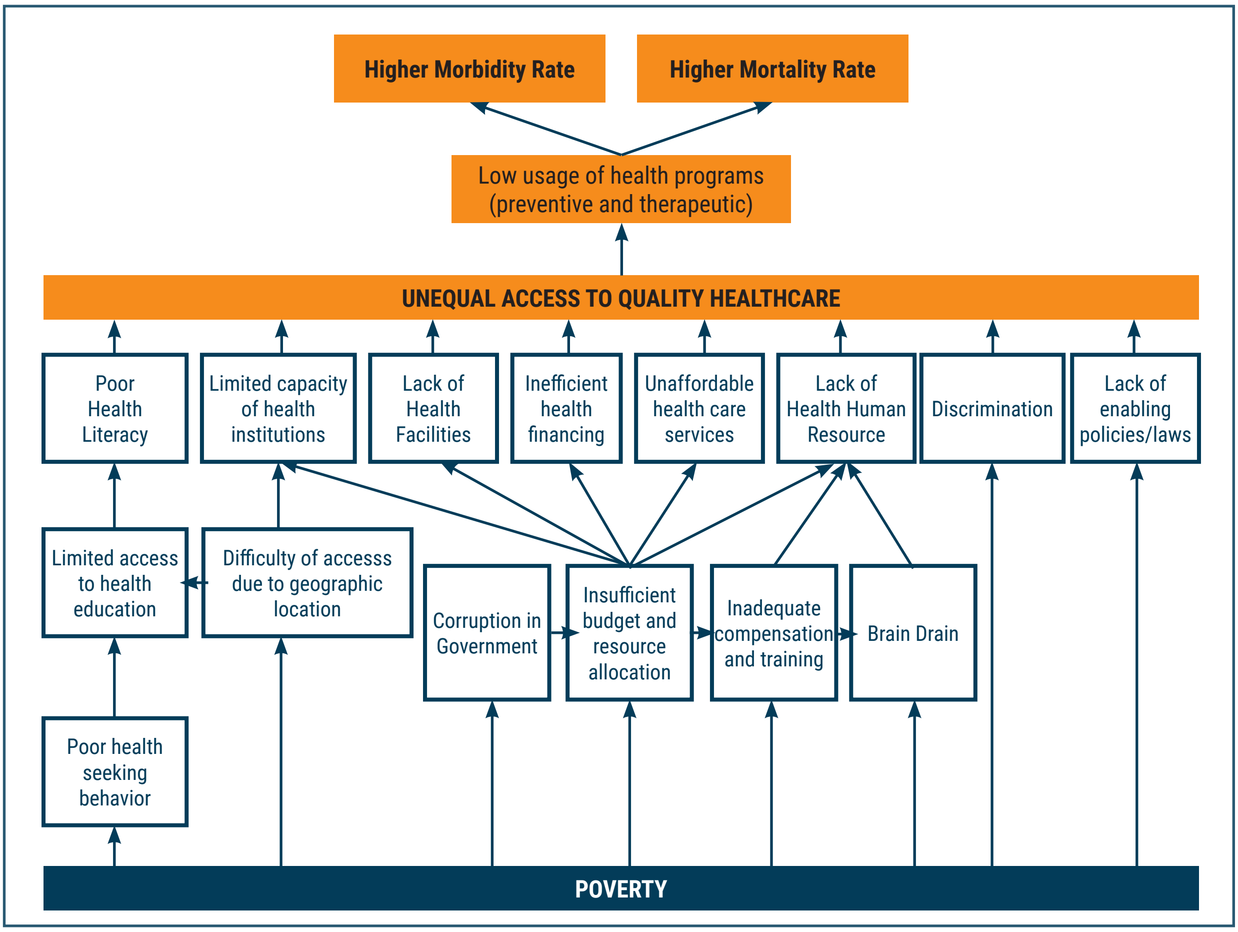


Figure 4.7_1. Health Group Problem Tree Analysis Output from the STI Foresight SWOT and TOWS Workshop on 22-23 October 2020.

The Science and Technology Application and Innovation System Areas

By utilizing the Nominal Group Technique, eight areas of scientific pursuit that are perceived to be most important in achieving UHC by 2050 were identified with 68 STIs identified through the Delphi method (Figure 4.7_2):

1. Health Information Technology. Far beyond replacing the use of paper, health information technology (IT) is a cross-cutting field that should be promoted in ways that synergize with other health system components, to address problems in UHC integration.These range from maximizing health workforce productivity through automation-driven efficiencies to fueling the sustainability of small-enterprise ancillary medical service providers, real-time authenticated payments, and other breakthroughs.

Health IT's interactions with other STI areas are also rich veins of potential breakthroughs for UHC. Connectivity can facilitate access by the health workforce to its own development tools, or by the populace to health literacy resources, to name only two examples. The Philippines has some catching up to do at the level of enabling environments such as national infrastructure, while opportunities abound for information technology (telepresence, Internet of Things (IoT)-enabled diagnostic devices, and artificial intelligence (AI)-assisted decision support and analytics, and more) to allow us to outgrow traditional or outdated pathways toward universal health care.

2. Health Policy and Systems Research. We have long understood that in the production of health, health policies themselves can be both dependent and independent variables, interacting also with other factors and the wider Philippine context (Atienza 2004).

Because complexity is part of UHC, it should be navigated using systems thinking and multidisciplinary approaches, all focused on health equity. Health policy and systems research (HPSR) in its short history has pioneered all three of these qualities in health, and it can and should be used further to help us in thinking about health systems, keeping pace with the evolution of disease management and information utilization, and grappling with health determinants far beyond health systems (Peters 2018).

The rise of HPSR is timely at this juncture, as our latest health reforms, learning from those of the 2000s, could perfect those of the 1990s that underestimated the challenge of important principles declared in the 1970s. Indeed, HPSR allows "governments to become learning organizations," to know what works and what does not, and why—an ability that could spell the difference between adaptive success and stagnant failure over a thirty-year foresight period (Peters 2018).

Health Policy and Systems Research

- Clinic management system
- Primary care algorithm
- Vaccination program
- Cost effectiveness evaluation system*
- Government policy
- Health informatics programs
- Health technology assessment
- Implementation science
- National health indicators

Health Financing

- Blockchain technology and payment system
- Attractive compensation for healthcare workers
- Efficient sin tax collection
- Health informatics
- IT architecture and tele-communication backbone
- Budget allocation on R&D
- Automated claims reimbursement system
- Real-time socialized payment scheme

Health Information Technology

- Electronic Health Records/ Health Information System*
- Telehealth platforms
- Artificial intelligence
- Data analytics
- Internet connectivity*
- Disease tracking
- Knowledge management
- Precision medicine
- Accessible public health databases
- Biomedical devices

Health Workforce Enhancement

- E-learning platform, Online learning, Massive Open Online Course (MOOC)*
- Manpower database*
- Virtual /augmented reality, use of robots for training
- Remote screening and monitoring of healthcare workers
- Diagnostic system for primary care physicians*
- Information system records*
- Proper compensation of healthcare workers
- On-demand learning modules

S&T Application and Innovation System Areas for the Achievement of Universal Health Care in 2050

Biotechnology

- Locally manufactured biomedical devices*
- Rapid and molecular diagnostics*
- Wearables and sensors
- 3D printing
- Robotics
- Natural products and therapy using natural products*
- Genomics
- Nano biotechnology
- Regenerative medicine and stem cell technology
- Assistive and supportive devices

Environment

- Green architecture
- Health waste management, disposal, and recycling*
- Biosensors for environment
- Antibiotic resistance monitoring (ARM)
- Health impact assessment
- Risk mitigation device
- Artificial intelligence
- Vaccination program
- Training of specialists
- Policy environment

Health Literacy

- Public health education and information*
- Digital platforms and electronic systems*
- Gamification
- Mobile health
- Community engagement
- Telehealth

Precision Public Health

- Omics technology
- Precision medicine
- Genome database development and access*
- Artificial intelligence
- Vaccination program
- Programs for affordable drugs
- Health information system*

Figure 4.7_2. The Top 68 STIs Identified in the Delphi Activity Covering All of the Eight Identified Priority Areas.

Note: STIs in bold with asterisk (*) are the 15 STIs that gained a high median criticalness score (median = 5 and 6) with high consensus among the participants (IQR = 0).

3. Health Workforce Enhancement. In any population, and for any health outcome, health improvements are only possible if structural determinants like human resources for health are addressed (Cometto and Witter 2013). Health workforce density is the most influential of the 16 indicators contributing to the UHC Service Coverage Index, ranking first overall among 183 countries, first among low- and middle-income countries, and third among high income countries (Reid et al. 2020).

Optimal health workforce management can also generate meaningful employment, bolstering economic growth and global health security (Cometto et al. 2020). However, the scope of health workforce development must surpass the usual health workforce density "targets". Better metrics should measure better practices. Dodd et al (2019) suggested the prioritization of five areas for the strengthening of primary health care (PHC) systems such as non-physician health workforce (NPHW) development, integrating non-communicable diseases (NCD) prevention and control, building managerial capacity, institutionalizing community engagement, and modernizing PHC information systems.

Community health workers, can improve the coverage, efficiency, and quality of PHC (Dodd et al. 2019), including in NCD prevention and management. Harnessing some NPHW cadres will also require administrative-regulatory considerations regarding the type and extent of their autonomy, recognition as primary care providers, and authority or privilege to prescribe, to bill for their services, or to provide access to hospital diagnostics and admission (McCleery et al. 2011).

Capacity-building encompasses pre-service and in-service health professional education and its associated technologies. Decision-support tools, especially if linked to health information systems may provide a much-needed boost to the quality and coverage of health services in remote locations (Dodd et al. 2019). However, the introduction of new technologies or treatments would likely entail end-user training and enabling environments for their proper use, and that all of the costs associated with these should be weighed alongside the costs and effectiveness of the interventions themselves (Nemec and Chan 2017).

Although task-shifting to NPHW cadres dominates UHC discourse, the larger goals of UHC can and will have implications in all manner of medical practice. The large unmet need for surgical care has prompted surgical task-shifting to both non-physician clinicians and non-specialist physicians at first level hospitals around the world (Falk et al. 2020). Essential surgical services should not be left out from comprehensive first-contact care, and often fall upon the available primary care physician (PCP) in many parts of the Philippines. The need to equip PCPs accordingly has been known for decades (Weddington et al. 1986) and calls for innovations in training, collaborative practice, and supportive policy (Kim et al. 2020).

4. Health Financing. As a field of study and practice, health financing has some of the most direct linkages to health equity and access. It is also evolving, not the least by the growing alliance among ethics, sociology, economics, the health sciences, and others in emerging fields that study and influence decision making itself.

The strategic value of health financing spans all of health development: from the pre-service stage as the great purchaser and stimulus of health care inputs, all the way through to the monitoring of its performance and distribution, if it is measured consistently and with nuance. No pursuit of UHC would be complete without enhancing our scientific understanding of the implementational tools for health financing, impacting the generation of funds; their proper allocation; how to safeguard and inform the processes of arriving at such decisions; the realities around actual expenditure and transfers; and the feedback and analysis of health intelligence from these processes.

Merely mainstreaming financial technology, or 'fin-tech', in health could be a game-changer in operationalizing UHC, granting such newfound powers in health as transparency, security, timeliness, public-private participation, and hopefully, redistributive justice. However, directing these capabilities toward the ultimate goal of health equity will require that the end-products of research and innovation in health financing engage with a wider range of issues. These new knowledge should extend upward to the national and global movements that influence prioritization of health and within health, as well as outward and downward to the sociological, psychological, and potentially neurochemical roots of decision making by patients, health providers, and policy makers alike.

5. Health Literacy. The widely-used World Health Organization (WHO) building blocks framework guides health system investments, but it focuses on the supply side of care and overlooks how much more human health is produced outside of clinical settings than inside them (Peters 2018; Remington et al. 2015). Addressing this gap, health literacy has emerged from being a "silent epidemic" to a forefront issue (Hersh et al. 2015). By empowering self-care in homes and communities, health literacy holds promise for UHC not only in driving demand and access to health services, but also in continuing the production of health before and after these services are rendered or instructed.

Stewards of health mistakenly assume that our patients can seek, understand, navigate, and interact with the touch points of our industry, such as prescriptions, explanations, and schedules (Kelly and Haidet 2007). Unfortunately, patients with low health literacy have poorer access to health care and suffer worse health outcomes (Johnson et al. 2013; Levy and Janke 2016) across a wide range of indicators. Most concerning is the concordance between the risk factors for low health literacy, and those for health inequity in general: the same markers of socioeconomic disadvantage predispose to both (Johnson et al. 2013). Health literacy is, therefore, highly relevant to UHC, and is an explicitly-declared goal in the opening clauses of the UHC Act.

It is fitting that some recommend universal health literacy precautions, given the futility of screening to detect which patients have low literacy (Hersh et al. 2015). There are in fact various tools and methods that are useful for patient encounters within and beyond the physician's clinic, and that are poised to diversify and, hopefully, increase in effectiveness through more proactive, participative, and integrated digital approaches (Johnson et al. 2013; Dunn and Conard 2018; Conard 2019). It is with a sense of urgency that this field is beginning to innovate. As it transitions from gaining a firm grasp of the problems and potentials of health literacy, it looks forward to deepening our knowledge of their mechanisms, and ultimately designing and executing solutions (Nutbeam et al. 2018). The literature reveals no shortage of ways in which health literacy can develop, including which interventions best enhance literacy, where and when it matters most, what materials and touch points patients must grapple with, and how to measure literacy, to name a few challenges.

6. Biotechnology. Biotechnology can be harnessed for UHC from biomedical and economic perspectives, which are not mutually exclusive. First, its capabilities can be directed to answer national health priorities in ways that all Filipinos can access, provided these directions are properly incentivized. Greenwood (2010) suggests steering the industry with viability-enhancing 'push' and revenue-enhancing 'pull' policies, market commitments, and other financing, policy, and regulatory options. Such as move is important because biotechnology has longer, and more costly, development cycles than traditional pharmaceuticals, and contends with more complex challenges from drug discovery and development to manufacturing and distribution. At all of these stages, STIs may introduce efficiencies that increase viability, as we can see for drug discovery (Bull et al. 2000). Second, the industry can also be strengthened as part of an innovation economy, and an Asian Bioeconomy, on a larger multi-Sustainable Development Goal (SDG) scale, retaining high-wage innovation talent, providing more inclusive jobs, and sustainably harnessing biodiversity (Pisupati and Srinivas 2015).

Domestic enterprises appear particularly advantageous for strategic reasons. As the Philippines transitions toward a higher income status, we must prepare for ineligibility for some forms of development assistance, including medical supplies (Balcha 2018). Domestic biotech companies can build local manufacturing capability to wean the country from dependence on foreign drug supplies, thus also avoiding some uncertainties that the COVID-19 pandemic brought to focus. Local enterprises' entry into the market can drive down prices of biologicals dramatically as foreign multinationals pivot to compete (Frew et al.

2008). Domestic companies can also proactively innovate business models that open up neglected markets, just as hundreds of franchises in India facilitate cold chains from warehouses to clinics in urban and rural poor areas (Frew et al. 2008).

In all respects, biotechnological progress should avoid the 'unacceptable trade-offs' for UHC, and instead support and align with evidence-based prioritization of health and equity needs (Norheim 2015). Tailoring the growth of the biotechnology industry to the country's specific needs rather than falling into the trap of merely shifting from less to more technology.

The need for biotechnology development may also be heightened by population growth and ageing, as well as UHC funding itself which can all further increase health care demand. However, policy, regulatory, and financing environments need to be conducive at sufficient magnitudes and timescales for this industry, to build businesses that can address UHC challenges (Greenwood 2010).

In this regard, the versatility of biotech innovation should be deliberately harnessed. The gains of nurturing biotechnology to the point of bringing its health benefits to all Filipinos will spill over into agricultural, industrial, food, and environmental sectors (Okonko et al. 2006). These should be pursued toward the inclusive and sustainable future we want.

7. Precision Public Health. The promise and birth pains of Precision Public Health (PPH) make it an area of STI work relevant to improving health for all Filipinos. Important questions still frame the jump-starting of this field (Weeramanthri et al. 2018). STIs can shed light on the "precision" aspects, and technologies themselves, their effects, and how to use them—particularly in relation to the classical tenets, techniques, and, especially, the health equity goals of public health. The concept exceeds its origins in genomics, and is more than a question of technological capability; in fact it calls for "a modernization of surveillance, epidemiology, and information systems, as well as targeted interventions and a population health perspective (Khoury et al. 2016). For developing countries, in particular, some experts advise a "back to basics" approach to PPH targeting improvements in birth and death registries, geographic disease surveillance data, laboratory capacity, and epidemiological know-how (Dowell et al. 2016).

Despite the lack of a consensus definition of 'precision public health', there are complementary proposals, and one undisputed feature is the centrality of data and informatics (Weeramanthri et al. 2018). This is expected to enable more granular epidemiological studies that can target interventions more precisely, and more preventively. Empowering this paradigm shift would require STIs to enhance the health sector's skills and tools in "epidemiology, data linkage, informatics, and communications", placing data and informatics at the heart of PPH in much the same way that epidemiology is at the heart of traditional public health (Weeramanthri et al. 2018).

Without this perspective, PPH “is at risk of becoming precision medicine at a population level” (Olstad and McIntyre 2019). Instead, it should be cognizant of the “route from cell to bench to person to population” (Weeramanthri et al. 2018).

Although the target outcomes of precision technologies are often expressed in the language of health services for individuals, albeit with a more preventive slant, major proponents of PPH envision that the end users of PPH as re-conceptualized for true public health can, and should, include community health systems (Rao 2019).

In a similar vein, the use of PPH technologies and approaches should be geared toward root causes. They should unpack, through higher-resolution analyses, the broad “master categories” of social position and their health effects, into nuanced understandings and treatments specifically targeting those most in need (Olstad and McIntyre 2019).

Rao (2019) observes that examples abound of how PPH can impact numerous challenges in health, but these largely come from developed countries, thus implying a transplantation imperative for STI in the Philippines, if PPH is to play its proper role in UHC.

8. Environment. The UHC Act is premised on a holistic view of health, reiterating national commitments to healthy living conditions that can be traced to our affirmation that health is a human right. The physical environment accounts for an estimated 10% of human health production, or up to 24% to 33% of global disease burden, with health effects mediated through various exposures and injuries (Remington et al. 2015; Prüss-Üstün and Corvalán 2006).

If these are ignored, health gains over the past decades can be eroded by various environmental threats to health (Whitmee et al. 2015). The Philippines is one of the most disaster-prone countries in the world, a fact that is self-evident annually through severe tropical weather and volcanic and tectonic activity, yet its vulnerable populations living in high risk areas has only grown (Picazo et al. 2013).

Neglected tropical diseases, enmeshed with ecosystems through pathogen life cycles and zoonotic vectors, continue to plague our poorest provinces perennially through dengue, malaria, and debilitating, and sometimes fatal, parasitoses.

There is a strong health equity angle to environmentally linked human health. Morbidity and mortality attributable to environmental causes disproportionately affect disadvantaged populations (Prüss-Üstün and Corvalán 2006). Our children lose eight times more healthy life-years from these illnesses versus children in developed countries (Prüss-Üstün and Corvalán 2006). Developing countries like ours face the greatest risks from climate change despite contributing the least to greenhouse gas emissions (Campbell-Lendrum and Corvalán 2007).

Hence, toward the goal of health for all, STIs addressing health through our environment would be attacking root causes and risks to which countless Filipinos are inescapably exposed, including the most disadvantaged among us. Health STIs may discover entry points for solutions coming from the realizations that economists are now coming to terms with.

For starters, the fact that 'ecosystem services' heretofore taken for granted are, in fact, legitimate and indispensable contributors to both productivity and health because they determine how humanity benefits or suffers from nature, whether tangible or intangible, such as through food and water, floods and outbreaks, and even recreation and spirituality (Whitmee et al. 2015).

Innovative technology can integrate, monitor, and help manage these ecosystem services (Whitmee et al. 2015). Scientists face communication and advocacy challenges as well in advancing the health-environment agenda, for as long as this agenda is fettered by public and political indifference, knowledge gaps, and implementation failures (Whitmee et al. 2015; Watts et al. 2018).

In health and climate change alone, there is much room to innovate using research investments focused on climate change and public health; the scale-up of climate-resilient health systems, including disaster response and adaptations in the food and agricultural sectors; city-level control of carbon emissions; expansion of access to renewable energy; and forging partnerships for collaborative work and political will (Watts et al. 2018).

Since the health-environment axis interfaces with other development agendas—green economy, environmental preservation, and social justice, to name a few—it is inevitably enriched by other frameworks with slightly different approaches but, ultimately, similar aspirations.

Conclusion: Bridging Universal Health Care and Science, Technology, and Innovation

The UHC is subject to imperative needs that are real, palpable, and which immediately affect human lives in the present. There is a sense of immediacy and urgency to a human rights-focused goal like UHC, in contrast to the elbow room afforded to this Foresight to proactively envision and work towards an ideal future. Since the identification of priority areas and STIs is prospective and capabilities-based in nature, there is always a need to reassess and reconnect the STIs back to UHC.

A UHC goal-driven approach could be implemented through a focused group discussion aimed at validating proposed attributes of Universal Health Care and connecting the STIs to these approved UHC attributes. The UHC attributes themselves could stand as proxies for UHC, e.g., as the criteria for scrutinizing the list of STIs. These attributes are expected to represent domains and yardsticks of technological progress, being aspects of UHC that such progress can attain.

The application of systems thinking methodologies would allow the identification of technologies that are cross-cutting, as these would be seen having outbound effects on multiple other technology areas and, perhaps, multiple UHC attributes. These can be visualized with technology trees that offer the advantage of showing the connections between, and among, the STIs themselves. These could inform planners as to whether an STI on the map should be given high priority—or low priority, as the case may be—insofar as how it leads to UHC.

At the moment of writing this Foresight, the Philippines' response to the COVID-19 pandemic revealed much about what is needed to secure the health of its people. There is concern that the lessons learned therefrom may be skewed toward COVID-19 itself at the expense of other health issues. However, health crises typically exacerbate existing conditions, so it is far more likely that the lessons learned from COVID-19 reinforce key directions and recommendations that would have been called for even without the pandemic, rather than counter or alter them. Many of the health system-strengthening solutions accelerated by the pandemic are quite useful for health system strengthening, in a horizontal cross-cutting sense, despite being precipitated for a vertical reason.

In fine, one of the returning points of feedback was that universal health care (as opposed to universal health coverage) should focus on health as a goal that includes a far more inclusive definition beyond health services as the target, and to incorporate societal factors like inclusive economic growth—an argument which is also grounded in the anchoring principles of the UHC Act.

SECTION 4.8
ENERGY

Prior to the COVID-19 pandemic, the Philippines experienced a renewed economic dynamism, growing at an average of 6.3% from 2010 to 2019 (World Bank 2020a). Along with economic growth, electricity consumption was also expected to increase by 2040 to nearly four times its 2018 level (Danao and Ducanes 2018). Energy demand is projected to reach 43,765 megawatts (MW) by 2040, almost four times the 2018 demand (DOE 2019). The 100% electrification target across the Philippines by 2022 is also likely to contribute to additional demand (ADB 2018). All these factors prompted interest in attracting power generation investments to meet the growing demand (Rivera 2019).

However, since the COVID-19 pandemic started in March 2020, operations of industrial facilities and commercial establishments have slowed down, and electricity generation and consumption have dropped (WESM-IEMOP 2020). Subsequently, the economic growth forecast for the country (ADB 2020a; World Bank 2020a) turned sour. The lower economic growth trajectory means that electricity demand targets have been reduced. The outlook for new investments in generation is especially bleak, given the current excess capacity (Ravago and Roumasset 2020a, b). When the economy picks up, the country may again face a problem of attracting sufficient investment in generation. While addressing the public health problem is and should be a primary concern, the country should also not lose sight of the need to attract sufficient investments for long-term economic recovery: What are the potential needs for 2040 or 2050?

Pre-COVID-19 or Pandemic Power Supply and Demand Indicators

Benchmarking power supply and demand indicators of the Philippines relative to other countries revealed that there is a limited supply of power in the Philippines vis-à-vis consumption (Table 4.8_1). In 2014, the Philippines had 17.95 gigawatts (GW) capacity serving 100 million Filipinos. In comparison, its neighbors, Thailand and Malaysia, had 44.83 GW and 32.46 GW of power capacity serving their populations of 68 million and 30 million, respectively. Electricity consumption per capita in the Philippines is the lowest compared to other ASEAN countries. In contrast, the price per kilowatt-hour (kWh) is the highest in the region. It should be noted that Thailand, Malaysia, and Singapore trade in electricity, and this potentially helps keep power costs low.

Table 4.8_1. Power Supply and Demand Indicators in Selected Asian Countries,2014

	Electricity Generation per capita [(a)] (kWh/cap)	Per capita electricity use [(b)] (kWh/cap)	Installed Electricity Capacity [(c)] (GW)	Share of renewables in electricity capacities [(d)] (%)	Population [(e)] (in million)
Philippines	772	633	17.95	32.86	v
Indonesia	901	789	53.87	12.25	253
Malaysia	4,773	4,388	32.46	20.06	30
Singapore	8,949	8,586	13.18	1.95	6
Thailand	2,523	2,508	44.83	18.05	67
China	4,153	3,590	1,405.03	30.94	1,364
Japan	8,066	7,444	311.53	26.88	127
South Korea	10,797	9,928	93.71	11.68	50

	Residential Prices [(f)] (USc05/kWh) (for 2013)	Industrial Prices [(g)] (USc05/kWh) (for 2013)	GDP USD at constant price and exchange rate (2005) per capita [(h)]	Electricity transport/ distribution losses [(i)] (kWh/cap)
Philippines	13.84	9.91	1,650	73
Indonesia	4.19	4.82	1,878	85
Malaysia	6.07	6.17	7,295	193
Singapore	12.32	11.44	37,203	44
Thailand	8.03	5.33	3,457	157
China	4.55	6.38	3,826	239
Japan	22.60	16.26	37,607	367
South Korea	8.82	7.87	24,550	364

Source: Ravago et al. (2018a)

Notes:

(a) Net Generation is the amount of gross generation less the electrical energy consumed at the generating station(s) for station service or auxiliaries. Note: Electricity required for pumping at pumped-storage plants is regarded as electricity for station service and is deducted from gross generation (EIA 2015)

(b) Net Consumption is the consumption of electricity computed as generation, plus imports, minus exports, minus transmission and istribution losses (EIA 2015)

(c) Installed capacity

(d) Renewables share in electricity production or generation

(e) World Development Indicators

(f) In real prices constant at 2005 USD cents

(g) Constant 2005 USD prices and exchange rate

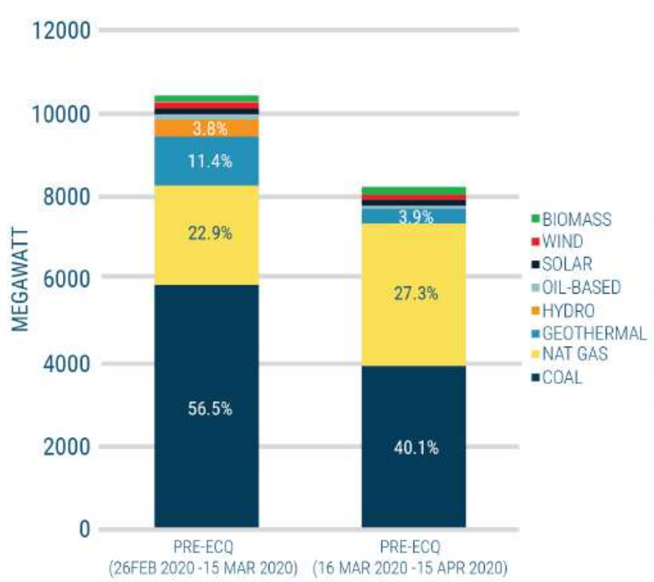
(h) Constant 2005 USD prices and exchange rate

(i) Transmission and Distribution Loss is Electric energy lost due to the transmission and distribution of electricity. Much of the loss is thermal in nature (EIA, 2015).

Industry Profile During COVID-19

Coal is typically characterized as a 'baseline' fuel because of its low fuel cost, high plant cost, and high ramping inefficiencies. However, during the lockdown period, coal has been serving as a marginal fuel, dropping from 56% to 48% of generation. Generation with natural gas decreased by 6%, as shown in Figure 4.8_1, but its share of total generation increased from 23 to 27%. Other sources stayed at about the same percentages, with solar and biomass generation increasing slightly, reflecting new generation capacity.

The reason for this paradoxical result lies in inflexibilities in legal rules and contracts. Since renewables are assured "must-dispatch" status as per the Renewable Energy Act (RA 9513), the system operator is required to accept whatever is generated. And while generation by natural gas is usually assumed to easily adjust to varying demands, what is not flexible is the supply of gas arriving by pipeline. The take-or-pay bilateral contracts with Meralco assure that minimum purchases of natural-gas generation reflect this inflexibility in gas delivery (and the extremely limited gas storage capacities). This leaves the burden of adjustment falling on coal plants, several which have had to temporarily shut down production.



WESM Generation Mix (Actual Generation)

Pre-ECQ Hourly Average, MW	Pre-ECQ %Share of Total	Fuel Type	ECQ %Share of Total	ECQ Hourly Average, MW
5,870	56.5%	COAL	48.1%	3,946
2,379	22.9%	NAT GAS	27.3%	2,241
1,180	11.4%	GEO	14.2%	1,161
396	3.8%	HYDRO	3.9%	320
130	1.2%	OIL	1.0%	78
160	1.5%	SOLAR	2.2%	177
122	1.2%	WIND	1.4%	117
154	1.5%	BIOMASS	1.9%	158

Figure 4.8_1. Generation Mix Before and After Enhanced Community Quarantine
Source: WESM IEMOP (2020).

Turning to the effect of the lockdown on electricity prices, average wholesale rates on the spot market fell by 55% during the lockdown period (Figure 4.8_2). Moreover, while wholesale prices used to peak around 2:00 pm, they now peak in the early evening, reflecting the shifting demand from commercial and industrial to residential consumers. The typically higher percentage of solar generation during the early afternoon hours also contributed to this pattern.

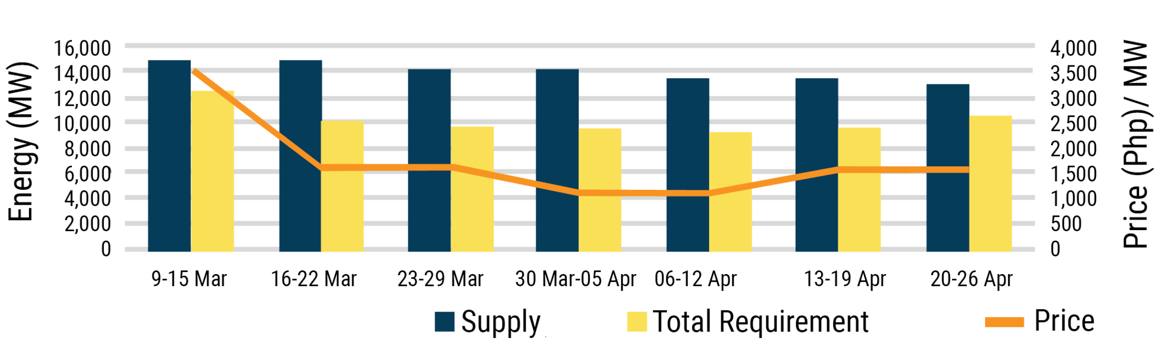


Figure 4.8_2. Average Supply and Total System Requirement (Energy + Reserve)
Source: WESM IEMOP (2020)

Pursuant to the Machiavellian credo to "never let a crisis go to waste," some observers have advocated government measures to accelerate the transition away from coal towards renewable sources of generation (EcoBusiness 2020). The implementing rules covering the Renewable Energy Act of 2008 specify an "aspirational target" of 35% renewables by 2030, which will be subject to regular review and assessment by the Department of Energy (DOE 2018).

The share of renewables in dependable capacity is already 31% (Table 4.8_2), suggesting that the target of 35% would be achieved much earlier than in 2030. However, DOE rules specify that the renewable portfolio standard (RPS) of 35% should be attained in terms of generation, not capacity (DOE 2017, 2018). This is somewhat more difficult since the share of renewable in generation during 2018 was only 23.4%, as shown in Table 4.8_3.

Table 4.8_2. Total Installed and Dependable Capacity per Technology, in MW.

	Installed				Dependable			
	2017	Percentage Share	2018	Percentage Share	2017	Percentage Share	2018	Percentage Share
Coal	8,049	35	8,844	37	7,674	37	8,368	39
Oil based	4,154	18	4,292	18	3,287	16	2,995	14
Natural gas	3,447	15	3,453	14	3,291	16	3,286	15
Renewable Energy	7,080	31	7,226	30	6,263	31	6,592	31
Geothermal	1,916	8	1,944	8	1,752	9	1,770	8
Hydro	3,627	16	3,701	16	3,268	16	3,473	16
Biomass	224	1	258	1	160	1	182	1
Solar	886	4	896	4	700	3	740	3
Wind	427	2	427	2	383	2	427	2
Total	22,730	100	23,815	100	20,515	100	21,241	100

Source: DOE-EPIMB (2018)

Table 4.8_3. Generation Mix, in GWh.

	2017	Percentage Share	2018	Percentage Share
Coal	46,847	49.6	51,978	52.1
Oil based	3,787	4.0	3,192	3.2
Natural gas	20,547	21.8	21,350	21.4
Renewable Energy	23,189	24.6	23,345	23.4
Geothermal	10,270	10.9	10,420	10.4
Hydro	9,611	10.2	9,406	9.4
Biomass	1,013	1.1	1,101	1.1
Solar	1,201	1.3	1,255	1.3
Wind	1,094	1.2	1,174	1.2
Total	94,370	100	99,765	100

Source: DOE-EPIMB (2018)
Note: Numbers may not add up due to rounding.

Despite the modestly higher gap to be filled, doing so does not make subsidies necessary. The Lazard levelized costs of electricity for wind and solar for the U.S. are already below those of coal and natural gas (e.g., Marachi 2020). Even though wind and photovoltaic power are intermittent resources, the costs of intermittency are quite modest, given the abundant opportunities for diversification, the falling costs of battery storage, and possibilities for demand management (Heal 2017).

Efficient Transition to Clean Energy

Many "clean energy" and "sustainability" devotees decry the pre-lockdown decline in the share of renewables and favor an accelerated transition to renewable energy (Ahmed and Dalusong 2020; EcoBusiness 2020). However, greater renewable mandates and subsidies would compromise the objectives of affordability, reliability, and security as required by the Electric Power Industry Reform Act of 2001 (EPIRA) and the Tax Reform Act of 2017 (RA 9136, RA 10963). In fact, there may even be a potentially high excess burden cost of renewable mandates and subsidies, as noted by Ravago and Roumasset (2018) and Roumasset et al. (2018). Mandates and subsidies also put the renewability advocates at loggerheads with the DOE's declared "technology neutral" policy whereby the generation mix should satisfy the criterion of least cost (Visaya 2017).

Economics provides a clear resolution of this apparent impasse. DOE needs only to interpret least cost to include the social cost of pollution. Given the rapid reduction in the cost of renewable energy, especially solar, and improvements in storage technology, the need is to facilitate an efficient energy transition, not to force it prematurely with costly subsidies.

Projecting the most efficient—i.e., the least social-cost—energy transition should take into account the declining costs of wind and solar power and the low costs of managing intermittency at levels needed to meet the RPS for 2030 (Heal 2017). For the decisions of private investors to be consistent with least social costs, taxes should reflect the marginal damage costs of pollution, especially from generation with coal. The Philippines has included coal and petroleum excise taxes as part of the 2017 tax reform (RA 10963). The Renewable Energy (RE) Act of 2008 has put in place several programs and policy instruments that aim to accelerate the development of renewable energy (RA 9513). Replacing these with pollution taxes can harmonize the quest for renewability with affordability and other objectives of EPIRA.

The social cost of pollution includes both the domestic cost from carbon emissions and the costs of local pollutants (sulfur oxides, nitrous oxides, and particulate matter) that impinge on health. The pollution cost of generation by coal are more than four times that for Open Cycle Gas-turbine and 20 times that for Close Cycle Gas-turbine (Jandoc et al. 2018). These numbers highlight the environmental benefits of transitioning away from coal towards generation by natural gas, as the Malampaya gas fields are depleted and by renewable sources.

Needs for the Future: Priority for Clean Technology

The use of “clean” rather than “clean-up” or waste treatment technologies is the very essence of the preventive and anticipatory approach to environmental protection and sustainable development (Uriarte 1990). Developing countries, like the Philippines, are in an excellent position to benefit from clean technologies since, in many cases, investments have not yet been made in conventional technologies, making it possible to leapfrog toward clean technologies. Clean technologies can enhance the country’s infrastructure, support underserved areas that lack access to electricity, clean water and sanitation, and create employment.

The water and energy sectors are two areas where there is ample scope for the application of clean technologies. Clean water and sanitation are essential for a healthy community. Clean technologies can improve the delivery of affordable clean water, minimize or prevent the production of wastewater effluents, and reduce the cost of water and wastewater treatment (Uriarte 2000). In the light of the fact that the Philippines is dependent on imported fuel for its energy needs and the energy sector is among the major contributors to greenhouse gas emissions and climate change, there is more than ample justification to give clean energy technologies the highest priority.

Many clean technologies have been developed globally, but most are initially located in industrialized countries. Accordingly, technology transfer is an essential part of the process to meet the future technology needs of developing countries. Traditionally, technology transfer occurs through foreign direct investments, imports, and licensing arrangements. But technology transfer involves not just the importation of hardware and software but, more importantly, it requires sharing of knowledge and adapting technologies to meet local conditions (UN 2011).

Clean Energy Technologies to Meet Future Needs

Sectors and industries have relied on several technologies to ensure access, production, and storage of energy. Among the most researched and developed technologies are biofuels, solar, and wind energy technologies and systems. Clean energy sources from the oceans have also been explored with the initial focus on ocean waves. In addition to these sources, technologies have been, and are being, developed to convert municipal solid waste into various types of solid, liquid, and gaseous fuels.

The least explored technology in the energy sector is nuclear power. Despite being an attractive and reliable source of energy, there are concerns regarding its use in tectonically active regions such as the Philippines as nuclear accidents prompted by earthquakes, volcanic activity, and other hazards posed severe health and environmental effects. In this regard, President Duterte issued Executive Order No. 116 on 24 July 2020 "Directing a Study for the Adoption of a National Position on a Nuclear Energy Program, Constituting a Nuclear Energy Program Inter-Agency Committee, and for Other Purposes" in recognition of an "imperative need to revisit the country's policy on nuclear energy and to determine its feasibility as a long term option for power generation."

There are now 445 nuclear reactors in 30 countries that are used for power generation. Another 57 are under construction. However, global capacity in nuclear power has been decreasing due to changes in government policies and safety concerns resulting from recent events like the nuclear accident in the Fukushima Daiichi power plant in Fukushima, Japan (NAST PHL 2019).

Several generations of nuclear reactors for power stations have been developed over the years. There are now four generations of nuclear reactors that vary by their fuel (uranium or thorium), moderator (graphite or heavy water) and coolant (either gas or liquid). Safety and security of nuclear reactors are of prime consideration. Competent national authorities are expected to regulate the safety and security of the design of nuclear power plants including the disposal of the radioactive wastes (POST 2014).

The need to reduce inefficiency and ineffectiveness in the distribution and use of energy has led to newer and more advanced technologies such as smart energy systems, microgrids, blockchain, and internet of things (IoT). The management of power supply to create more resilient energy infrastructure and cost-savings are made possible by energy storage technologies such as batteries, thermal, mechanical storage, hydrogen, and pumped hydropower (Figure 4.8_3).

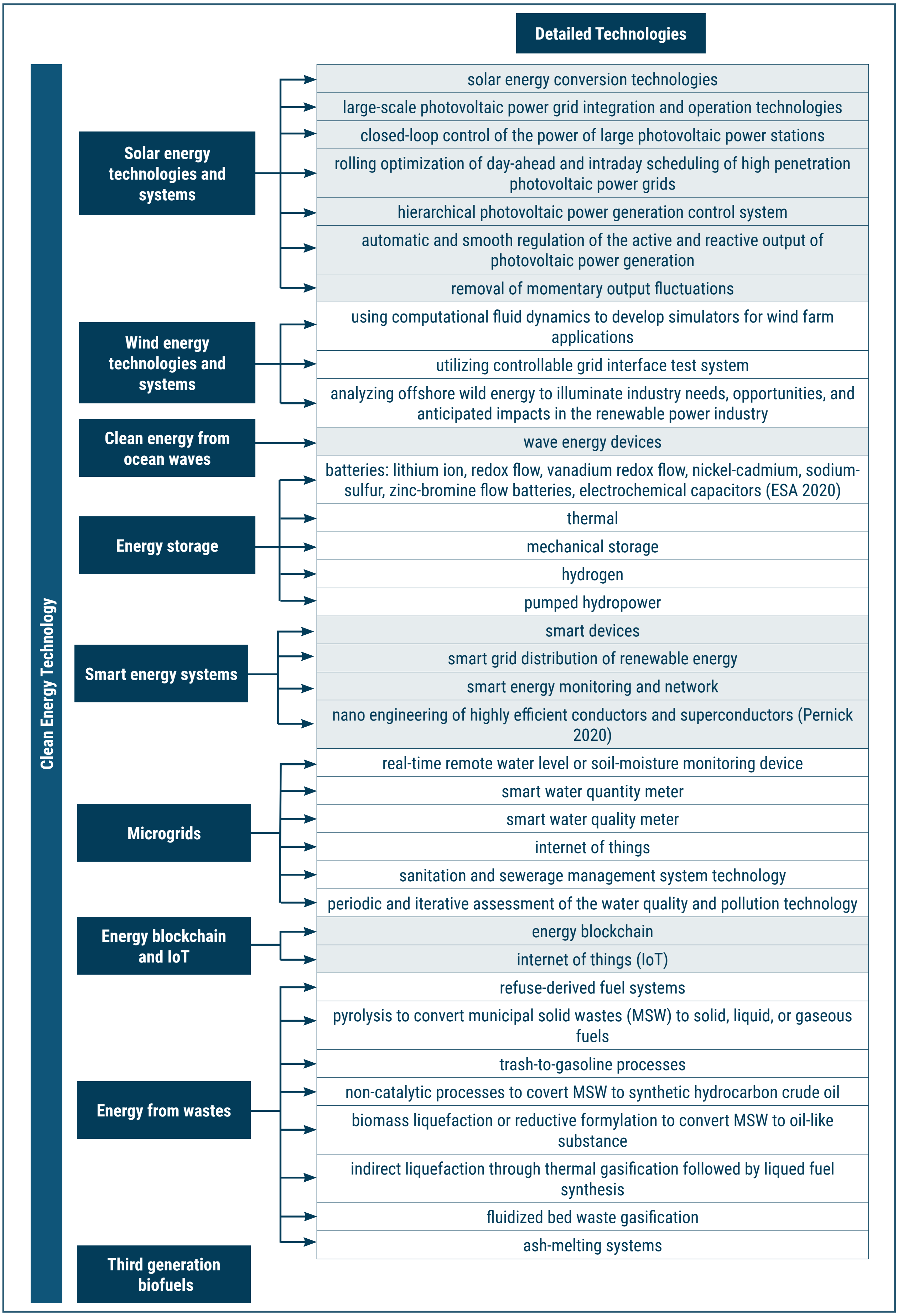


Figure 4.8_3. Clean Energy Technology
Sources: Uriarte (2008, 2010, 2017), Liu (2015), Clean Energy BC (2015), Lund et al. (2017), Ellsmoor (2018), WETO (2018)

The Future of Energy in the Philippines

Total Final Energy Consumption

In 2016, the country's total final energy consumption reached 33.1 million tons of oil equivalent (MTOE), which is up by 8.4% from 30.5 MTOE in 2015. The transport sector accounted for more than one-third of the total energy consumption (Figure 4.8_4).

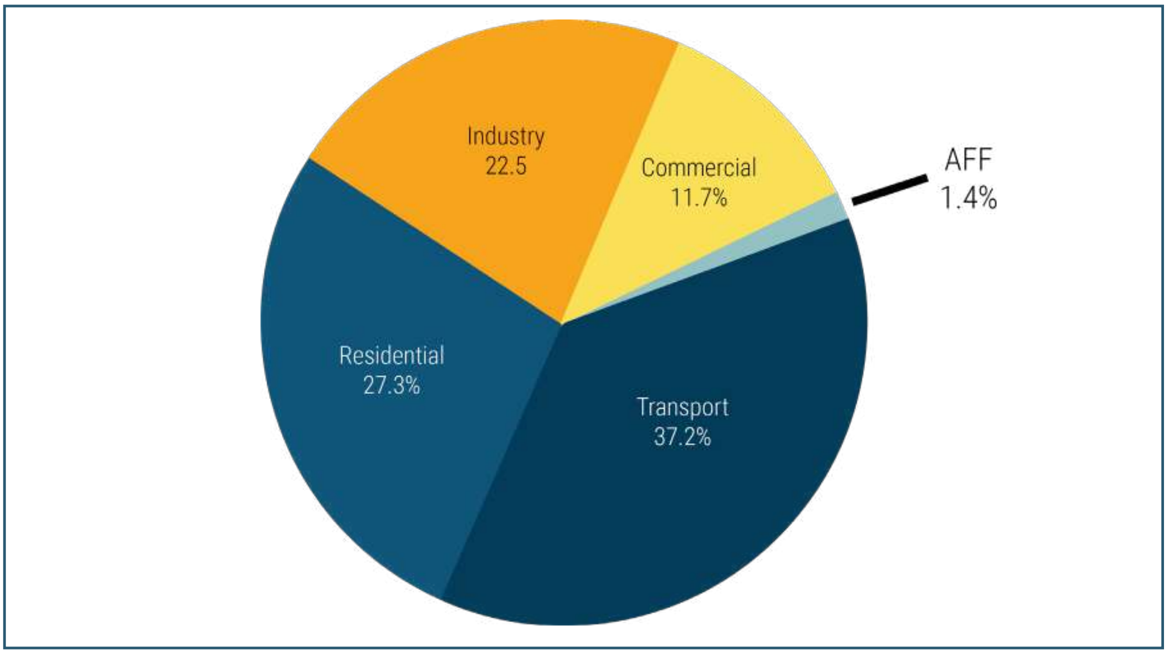


Figure 4.8_4. Total Final Energy Consumption by Sector (2016), Percentage Shares
Source: DOE (2019)

Petroleum products garnered the bulk of the country's total final energy consumption, with a 49.3% share (Figure 4.8_5).

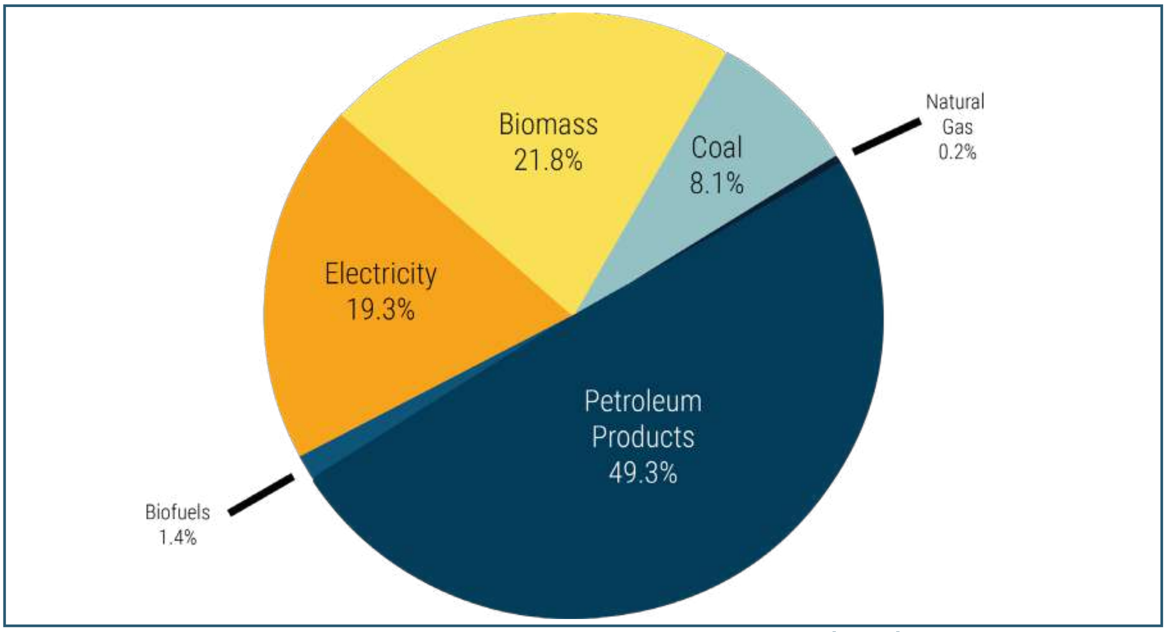


Figure 4.8_5. Total Final Energy Consumption by Fuel Shares (2016)
Source: DOE (2019)

Total Primary Energy Supply

For 2016, the country's total primary energy supply (TPES) reached 53.2 MTOE, 3.7% higher from its 2015 level of 51.3 MTOE. Indigenous energy resources also increased from 26.9 MTOE in 2015 to 29.4 MTOE in 2016. Oil and coal remain to have the biggest cumulative share at 34.8% and 21.9%, respectively (Figure 4.8_6).

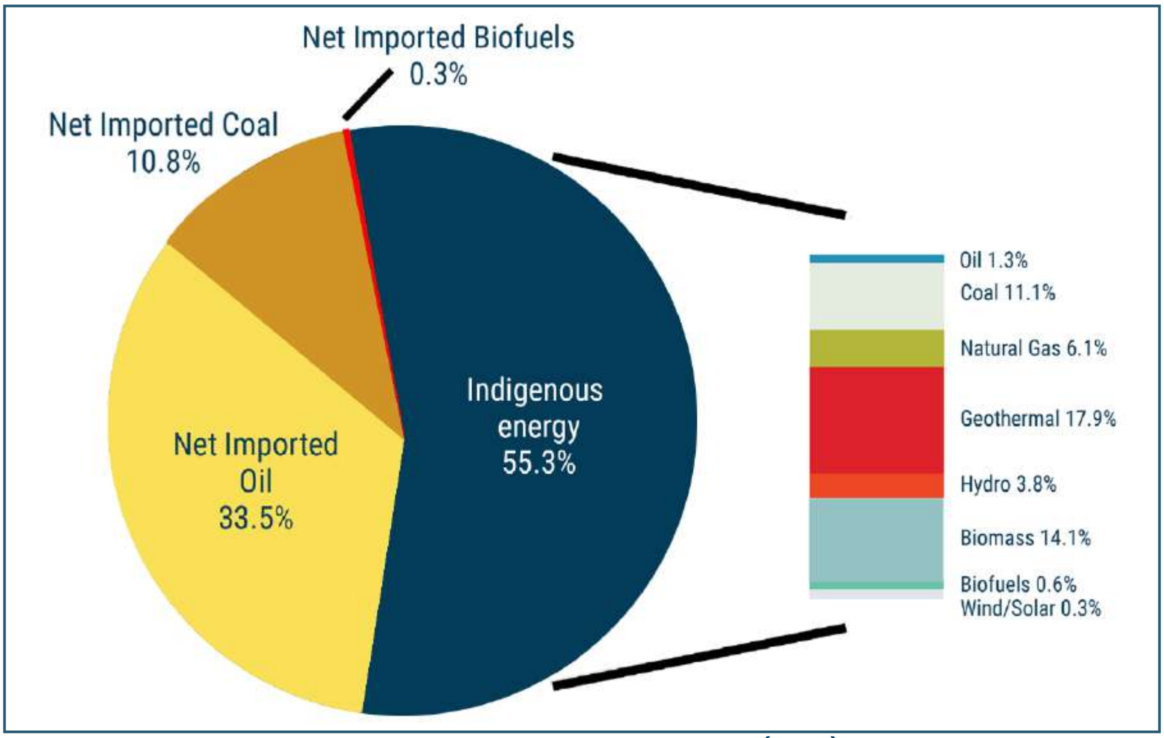


Figure 4.8_6. Total Final Energy Consumption by Sector (2016), Percentage Shares
Source: DOE (2019)

Projected Total Final Energy Consumption

The country's total final energy consumption (TFEC) is expected to increase at an average rate of 4.3% annually, from 33.1 MTOE in 2016 to 91.0 MTOE by 2040 (Figure 4.8_7). The transport sector will continue to take the biggest share, with a 38.2% average across the planning period (DOE 2019).

Figure 4.8_8 indicates that as the transport sector continues to be the biggest energy consumer among different sectors, petroleum products will continue to account for the biggest bulk of the TFEC. Despite volatility in oil prices, demand for petroleum products will increase by 4.5% per year (DOE 2019).

As for electricity, the Philippines has an existing dependable capacity of 17,925 MW. The country's demand for electricity will increase to 30,189 MW by 2030 (Saulon 2016). This translates to almost 1,100 MW per year. Currently, the country has a number of projects committed to delivering 6.178 MW.

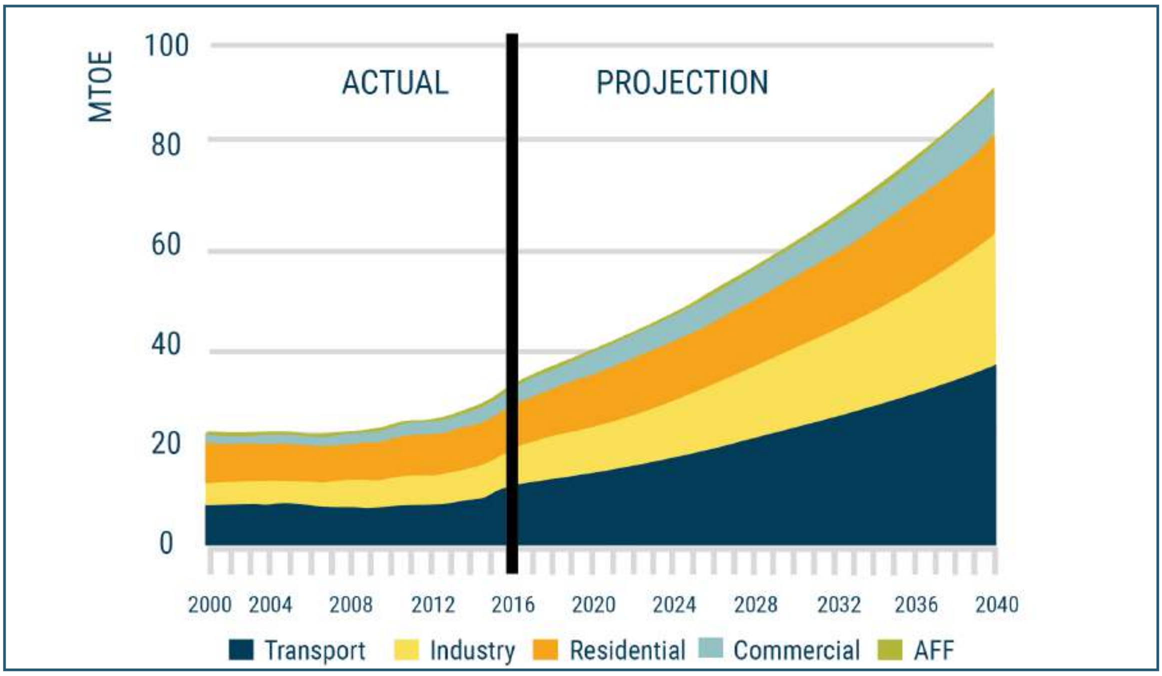


Figure 4.8_7. Total Final Energy Consumption, by Sector (2000–2040)
Source: DOE (2019)
Note: Energy consumption expressed in terms of million tons of oil equivalent (MTOE)

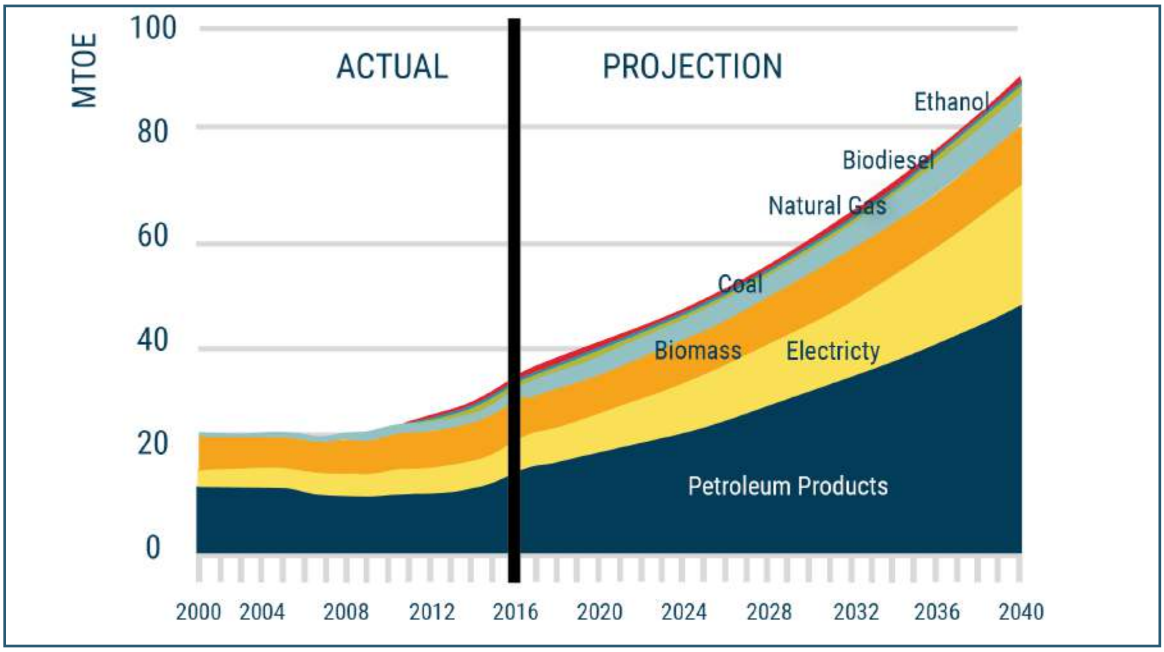


Figure 4.8_8. Total Final Energy Consumption, by Fuel (2000–2040)
Source: DOE (2019)
Note: Energy consumption expressed in terms of million tons of oil equivalent (MTOE)

Projected Total Primary Energy Supply

The country's total primary enery supply (TPES) will grow at an average rate of 4.4%, reaching 148.1 MTOE in 2040 under business as usual scenario. Under this scenario, oil and coal will still dominate the supply mix, which will account for 67.1% of the TPES. Meanwhile, under a clean energy scenario, growth will be slightly slower at 4%, reaching 137.8 MTOE. Aggregate contribution of oil and coal will also be slightly lower at 60.4%. Moreover, share of RE sources will grow from 19.7 MTOE in 2016 to 29.2 MTOE by 2040.

Current Issues faced by the Energy Sector

1. **Philippines' energy self-sufficiency is only at 53.5%, which fell short of the 60% target in 2015.** Out of the 50.4 MTOE energy supply of the country, local energy is only comprised of 26.9 MTOE.

2. **Power generation has increased, but it is still insufficient to meet growing demand which worsened feedstock security concerns.** Installed capacity grew by 4.6% from 17,944 MW in 2014 to 18,765 MW in 2016. As for renewable energy, only a total of 7,013.9 MW of renewable energy has been installed out of the potential 14,499.8 MW. Hydropower plants comprise 19.2% of the country's installed RE capacity, but hot or dry weather conditions affected the reliability and adequacy of energy supply. Natural gas, on the other hand, powers 23% of the Luzon dependable capacity, however depletion of the gas field, expiration of existing contracts, and disputes in the West Philippine Sea threaten energy security. In fact, as of this writing, Shell already ceased operation in this gas field. Lastly, private sector continue to invest in coal-fired power plants due to faster development and operation in response to the country's requirements. However, this energy source is also threatened as Indonesia, which supplies 70% of the Philippines' coal import needs, placed a moratorium on coal shipments due to the risk of kidnappings and piracy in the West Philippine Sea.

3. **Development of transmission network and distribution facilities was hampered by issues of right-of-way, security, and resilience to natural calamities.** Lack of interconnection between Luzon, Visayas, and Mindanao deters the possibility of using surplus from one grid to another, and etc.

4. **Gaps in electricity access, especially in the rural and off-grid areas, still remain despite considerable effort to pursue nationwide distribution.** Household electrification level reached 89.61% (20.36 million out of 22.72 million) in July 2016. Much is still needed to achieve Sustainable Development Goal 7 of universal energy access by 2030.

5. **More work is needed to optimize the benefits of demand-side management.**

6. **Indigenous supply of biofuel is still way below the increasing blending requirements (i.e., RA 9367) of the local fuel industry.**

7. **The Philippines' electricity rates remain amongst the highest in Asia.** This is due to a lack of state subsidy for privately generated, transmitted, and distributed power supplied. Feed-in-tariff,

universal charges, VAT, and system losses are also passed to the consumers. Other problems include minimal competition and alleged market manipulation. Reducing electricity cost is vital, but a balance between rates, environmental implications, service reliability should be achieved.

The foresight towards 2050 is the improved well-being of the Filipinos. Efficient transition to clean energy should be accompanied by investment coordination in generation, transmission, and distribution; government investment in the transmission highway; regulatory oversight coordination in support of a competitive market; reconciling two seemingly contradicting instruments, the EPIRA and RE laws; reform of the electric cooperatives; and investment in R&D (Ravago et al. 2018a, 2018b).

SECTION 4.9
WATER

The Philippines has an annual rainfall of 2,500 mm and is endowed with vast water resources with a total area of 2,257,499 sq km consisting of marine (bays), inland waters (rivers and lakes), and groundwater. Groundwater reservoirs have an estimated storage capacity of 251 billion cu m and a dependable supply of 126 billion cu m per year (DENR 2016). The major river basins of the country are in critical condition that endanger surface water potential as reflected in the 2010 land use and land cover map of the Philippines (Cruz 2018). Barely 25% of the total area of these basins are covered with forest vegetation with six river basins having less than 10% forest cover. Furthermore, only about 27% of the 688 classified water bodies in the country have potable water. Many of the major rivers and lakes are heavily polluted. For example, out of the 40 water bodies monitored as sources of drinking water supply, only 28% conform to the criterion for total suspended solids (DENR-EMB 2014).

Water Uses

According to National Water Resources Board (NWRB), the total water permits granted in 2010 was for 86 billion cu m annually (approximately 60% of the country's water availability), consisting of 78% for irrigation water, 8% for domestic water supply and the rest for industrial, commercial, and other uses. Comparative trend analysis across the three sectors indicates that both the domestic and industrial sectors have increasing water demand while that of agriculture is declining (NWRB 2016).

Regional Water Demand and Supply

Water scarcity in the Philippines is real. Past studies have shown that water shortage in the country is due to the following (Rola et al. 2018):

- population increase
- urbanization
- economic growth and weak water governance characterized by fragmented and multiple institutional arrangements to manage water resources
- lack of effective policy instruments
- weak enforcement of environmental protection policies

Climate change is also expected to alter rainfall patterns that will affect stream flow, dam operation, water allocation, domestic water supply, irrigation, hydropower generation, depth and recharge of aquifers, water quality, watersheds, and fisheries (Lasco 2012).

The only available master plan showed that by 2025 water resources regions II, III, IV, and VII will not be able to meet the projected demand (Figure 4.9_1) (JICA and NWRB 1998). However, the 2016 NWRB surface water data already showed that in five (Regions I, II, III, IV, and VII) of the 12 water resources regions in the country, demand has surpassed the supply (Pulhin et al. 2018). A negative figure is also recorded for the whole country.

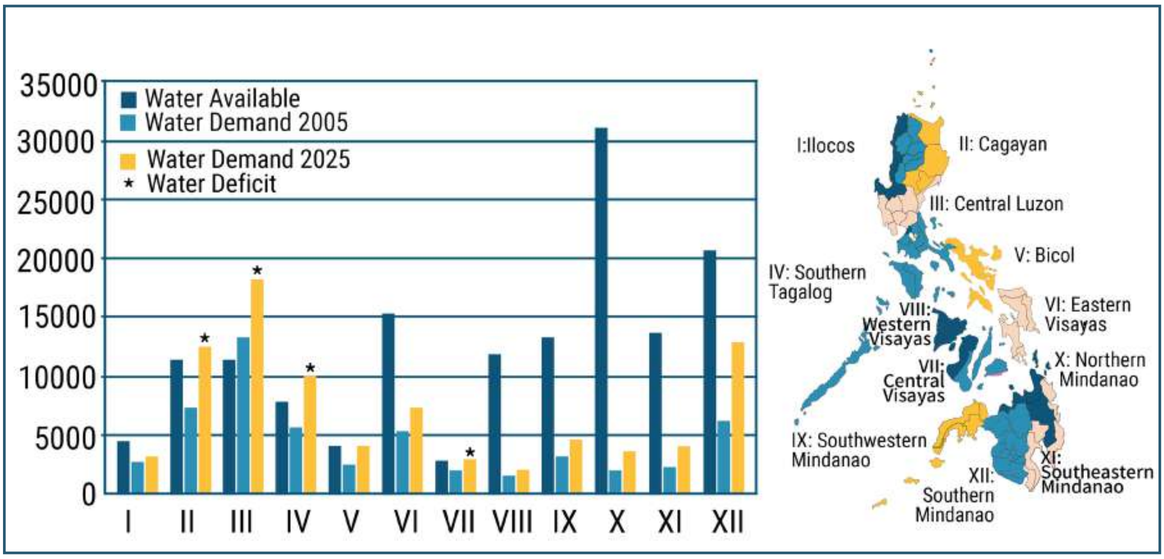


Figure 4.9_1. Projected Regional Supply and Demand Situation in Thousand cu m (2005-2025)
Source: JICA and NWRB (1998)

Global Outlook for Water Use Towards 2050

Ertug and Hoekstra (2014) identified the drivers that will influence the level of water consumption and pollution as follows:

- Global water footprints
- Population growth
- Economic growth
- Production and trade patterns
- Consumption patterns (dietary change, bioenergy use)
- Technological developments

Changes in consumption pattern will reduce water footprints; intensive biofuel use will increase water use; and dietary preferences will affect water demand. Population growth will remain the major driver of change in water use. Thus, policy reforms will be needed towards a more sustainable water use, despite population growth.

Science, Technology, and Innovation Foresight on Water

Given the growing needs for water resources and the technologies at hand, it is important to be cognizant of water-related future scenarios (events or conditions) and current status that need inputs based on science, technology, and innovation (STI) or require modification or interventions from an STI framework.

Domestic Water Supply

About 90% of the country's population source water from groundwater and the rest from surface water in rivers or lakes, such that when drawn in large amounts, water becomes a finite, limited resource. Groundwater is susceptible to contamination. On the other hand, surface water sources from rivers or lakes are more sustainable since they are replenished annually during the wet months. Thus, the need to build water impoundments from properly designed large-scale or major reservoirs to small-scale water cisterns to collect rainwater in households. The groundwater aquifer can also serve as a water reservoir by installing infiltration galleries at strategic recharge areas. Natural lakes, like Laguna de Bay, can also serve as reservoirs. Finally, there could be large-scale inter-basin water transfers for domestic water supply purposes. For instance, the Pampanga River has been suggested as an alternative water source for Metro Manila (Tabios G 2019), which can be conveyed by a 40-km aqueduct, from Calumpit, Bulacan to Quezon City.

Irrigation Water Delivery

The bulk of irrigation water is utilized by 1.4 million ha of rice farms. A large portion of the irrigation water delivery is serviced by the so-called national irrigation systems built and maintained by the national government. In Asia, the estimate of the water requirement for rice production is 15,000 to 31,500 cu m per ha per year, amounting to 21 to 44 billion cu m per year for 1.4 million ha of irrigated rice. In this case, even at the high side, over 50% (i.e., relative difference of 67 and 44 billion cu m annually equivalent 23 billion cu m) of irrigation water is wasted which could have supplied three or more times the annual domestic water supply needs of the country. To reduce this wastage, developments in precision agriculture use an array of sensors to monitor soil moisture in order to determine volume and timing of the delivery of irrigation water. Remote sensing using satellites can provide real-time data, even at 15-minute intervals, on water level or soil-moisture, and can be used in tandem with in-situ monitoring devices.

Floods and Flood Risk

The meteorologic factors that generate major floods in the Philippines are the interplay of typhoons, monsoons, hovering intertropical convergence zones, and thunderstorms. The islands are of volcanic origin, and our rivers have steep slopes with headwaters (i.e., at the ridge) that are several hundred meters high and run quickly to the sea. Major cities are also built in the deltas or alluvial fans of these rivers. Flooding in urban settings has other dimensions besides the meteorological and hydrological such as economic, social, or human factors. For instance, in Marikina River, several flood mitigation plans have been pushed in the last decades, such as the Mangahan Floodway with Paranaque Spillway to temporarily store water in Laguna de Bay and alleviate flooding along the downstream Pasig River where major cities of Makati, San Juan, and Old Manila including Malacañang Palace can be spared during the passage of the storm or typhoon. After the storm passes, the floodwaters are to be evacuated from the lake to Manila Bay through the Paranaque Spillway, but the spillway was never built.

A small-scale flood reduction scheme is rain harvesting, so storm rainfall can be stored in household cisterns or storage tanks instead of flowing directly into the streets. However, a reasonably sized cistern can only accommodate so much rain. Perhaps the rest of the storm rainfall (once the storage tanks are full) can be directed to a constructed infiltration gallery built around the house to deep percolate into the ground (subsurface).

Water Quality Maintenance and Pollution Control

With rapid urbanization and industrialization compounded by inadequate local or national sewerage and sanitation facilities, there is massive pollution in most of our water bodies covering rivers, lakes, and estuaries. In the environmental monitoring report of the World Bank (2007), the biggest source of pollution is domestic waste, which accounts for almost 48% of the water pollution, followed by agricultural waste (37%) and industrial waste (15%). STI can promote holistic planning and management of sanitation and sewerage systems, including waste treatment, which requires a periodic and iterative assessment of the water quality and volume, including types of pollutants.

Water Governance as a Science, Technology, and Innovation Concern

It is said that, in the Philippines, the water crisis is a crisis in water governance (Rola et al. 2015a, 2015b). A major problem is the overlapping and fragmentary jurisdiction and authority in the water resources management framework in the Philippines. Whatever governance structure is adopted, STI can assist in the adoption and employment of a framework for sustainability, which utilizes scientific tools (physical, social, economic, behavioral sciences) and engages stakeholders (academics, professionals, government, civil society) to solve problems through an iterative process of collaborative learning, research, and consensus-building (Tabios 2020).

Clean Water Technologies to Meet Future Needs

Finally, it will be worthwhile to enumerate here available clean water technologies to augment domestic water supply, maintain water quality, and control pollution (Figure 4.9_2).

		Detailed Technologies
Clean Water Technology	Rainwater Harvesting	Small-scale water cisterns to cellect rainwater in households
		Water reservoir through groundwater aquafer with infiltration galleries at strategic recharge areas
		Infiltration gallery built around the house to deep percolate into the ground (subsurface) to minimize flood risk in case storage tanks for rainfall are full
	Membrane Technology	Membranes with high chemical stability for wastewater recovery
		Membranes and modules with antifouling properties
		Large membrane surfaces with homogeneous characteristics
	Seawater desalination with electricity	Seawater Reverse Osmosis integrated with pressure retrarded osmosis and forward osmosis
	Algae-based wastewater treatment	Fluidized bed algae-based wastewater treatment system
		Fixed-bed algae-based wastewater treatment system
		Suspended algae-based wastewater treatment system
	Nutrient recovery from wastewater	Biological assimilation through constructed wetlands for phosphoroous and nitrogen removal from wastewater
		Nutrients recovery by microalgae-based processes
	Smart water monitoring	Real-time remote water level or soil-moisture monitoring device
		Smart water quantity meter
		Smart water quality meter
		Internet of Things
		Sanitation and sewerage management system technology
		Periodic and iterative assessment of the water quality and pollution technology
	Constructed wetlands and phytoremediation	Phytoextraction or phytoaccumulation
		Phytovolatilization
		Phytostabilization or phytosequestration
		Phytodegradation
		Phytofiltration or Rhizofiltration or rhizodegradation

Figure 4.9_2. Clean Water Technologies for Future Needs

Source: Prasad et al. (2015), Sengupta et al. (2015), Zion et al. (2015), Fernandez et al. (2018), Jha et al. (2019), Uriarte 2018 (2019), Wollman et al. (2019), Schunke et al. (2020)Uriarte 2018 (2019), Wollman et al. (2019), Schunke et al. (2020)

Rainwater harvesting. Rainwater harvesting is a key intervention measure in adaptation and reducing vulnerabilities (Uriarte 2018). Rainwater harvesting has been a neglected opportunity in water resource management, and is an effective coping strategy in variable rainfall areas. It can enhance ecosystem productivity and sustainability by augmenting water supply for agricultural, domestic, and industrial use.

Membrane technology. Membrane processes like microfiltration, ultrafiltration, nanofiltration, and reverse osmosis could be a solution for advanced physical treatment of water and its desalination for drinking purposes as well as for agro-industrial uses. The advantages of membrane technology include its modular nature, allowing application at large or small scale, better water quality, a relatively small carbon footprint, and in some cases, lower energy usage.

Seawater desalination with electricity production. Improvements in Reverse Osmosis (RO) technology have led to seawater RO (SWRO) becoming the dominant form of large-scale desalination around the world. However, the specific energy consumption of SWRO remains substantially higher than that for surface water treatment. The high-pressure pumping required to overcome the osmotic pressure in saline feedwater results in a saline concentrate stream, which is highly pressurized. Energy recovery devices (ERDs) are commonly used to harness this hydraulic energy. Piston-driven ERDs follow a similar process of hydraulic energy exchange, with the transfer of energy between concentrate and feed occurring inside hydraulic cylinders.

Algae-based wastewater treatment. The most efficient approach to reduce the pollution of water resources with nitrates, phosphates, and high organic loads is to remove these components at the point of origin, i.e., at the processing sites. However, conventional biological wastewater treatment systems are often unable to fulfill this task because the pH values, high organics, or temperatures are often non-compatible to microbiological physiology. On the other hand, microalgae, conventional and extremophilic, when used in cleaning waste water can play an important role in a circular bioeconomy by providing high-quality products, such as proteins, lipids, and colorants.

Smart water monitoring. Smart Water Monitoring System for real-time water quality and usage monitoring consists of a Smart Water Quantity Meter and a Smart Water Quality Water. The former is to ensure water conservation by monitoring the amount of water consumed by a household and notifying the same to the consumer and the authority while the latter checks the purity of potable water that the consumer receives, by measuring pH, temperature, turbidity, dissolved oxygen, and conductivity using remote sensing technology. Violations in either the usage limit or changes in water quality are immediately notified to the consumer and authority, and an alert signal is generated by the system.

Constructed wetlands and phytoremediation. Constructed wetlands have a great potential for efficient and effective removal of organic contents and nutrients from wastewater effluents. In the US, commonly used hydrophytes in the constructed wetland are *Phalaris arundinacea*, *Schoenoplectus tabernaemontani*, *Cyperus alternifolius*, *Zizania palustris*, *Juncus effusus*, etc. The main biological processes occurring in wetlands that result in removal of pollutants and nutrients are photosynthesis, respiration, fermentation, nitrification, de-nitrification, and phosphorus removal (Uriarte 2019). On the other hand, phytoremediation is a plant-based approach that takes advantage of the ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues. The main physiological steps in phytoremediation include stimulation of microorganism-based transformation by plant exudates; slowing of contaminant transport from the vegetated zone due to adsorption, and increased evapotranspiration; and plant uptake, followed by metabolism or accumulation (Uriarte 2018).

SECTION 4.10
ENVIRONMENT AND CLIMATE CHANGE

This section focuses on the projected effects of climate change and other environmental hazards on the possible uses of the environment/natural resources. The descriptions herein are built on the historical and recent trends of natural resources and their uses at the national, and global levels that are covered in Section 1.5.1 and Section 2.2, respectively. Current practices, technologies and policies related to natural resources management and utilization are described and assessed as to their sufficiency to achieve the targets desired for the natural resources sector. The results of this assessment could be used as bases to determine what new or additional practices, technologies and policies may be needed to satisfactorily achieve sustainability, resilience and competitiveness on or before 2050.

Climate Change

It is estimated that the planet has warmed by about 1.0°C above pre-industrial levels (IPCC 2018). It is likely that the average temperature will increase by 1.5°C between 2030 and 2052. The impacts of global warming will be felt by natural and human systems, exacerbating existing risks to livelihoods, biodiversity, human and ecosystem health, infrastructure, and food systems (IPCC 2019a). In addition, warming of the oceans will affect coastal ecosystems through intensified marine heatwaves, acidification, loss of oxygen, salinity, intrusion, and sea level rise (IPCC 2019b).

Future climate projections for the Philippines are consistent with these global projections. Relative to air temperatures in 1970-2000, the country's air temperature is expected to rise by as much as 4°C by the year 2100 (Figure 4.10_1). Yet even as early as mid century, in 2050, air temperature will be between 1°C to 2°C hotter than the same baseline. Rainfall amount and seasonality is less homogenous for the country, with some parts becoming wetter and others becoming drier (Figure 4.10_2). Future trends on tropical cyclones are more uncertain, with models suggesting reduced frequency but higher intensity (DOST-PAGASA 2018).

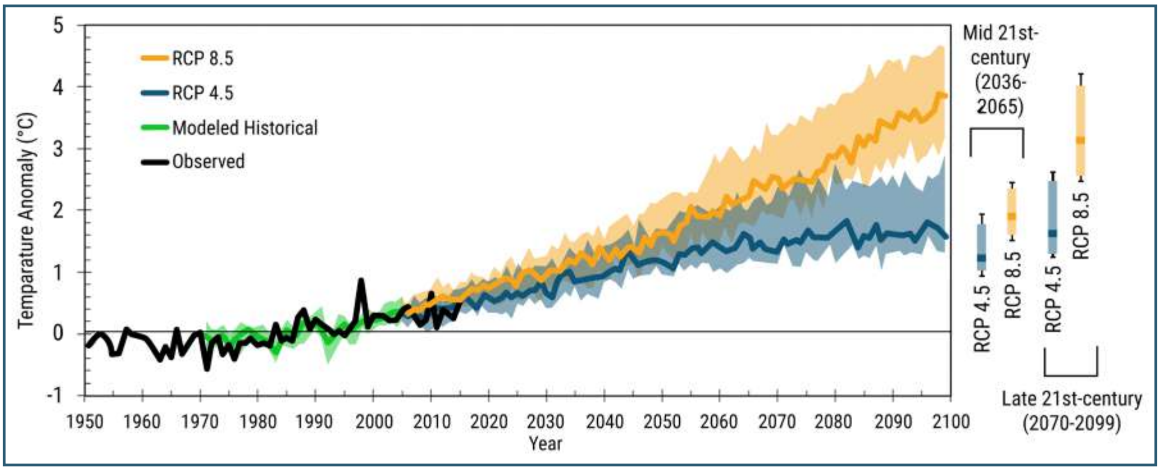


Figure 4.10_1 Projected Air Temperatures for the Philippines with Climate Change
Source: DOST-PAGASA (2018)
Note: RCP - Representative Concentration Pathway

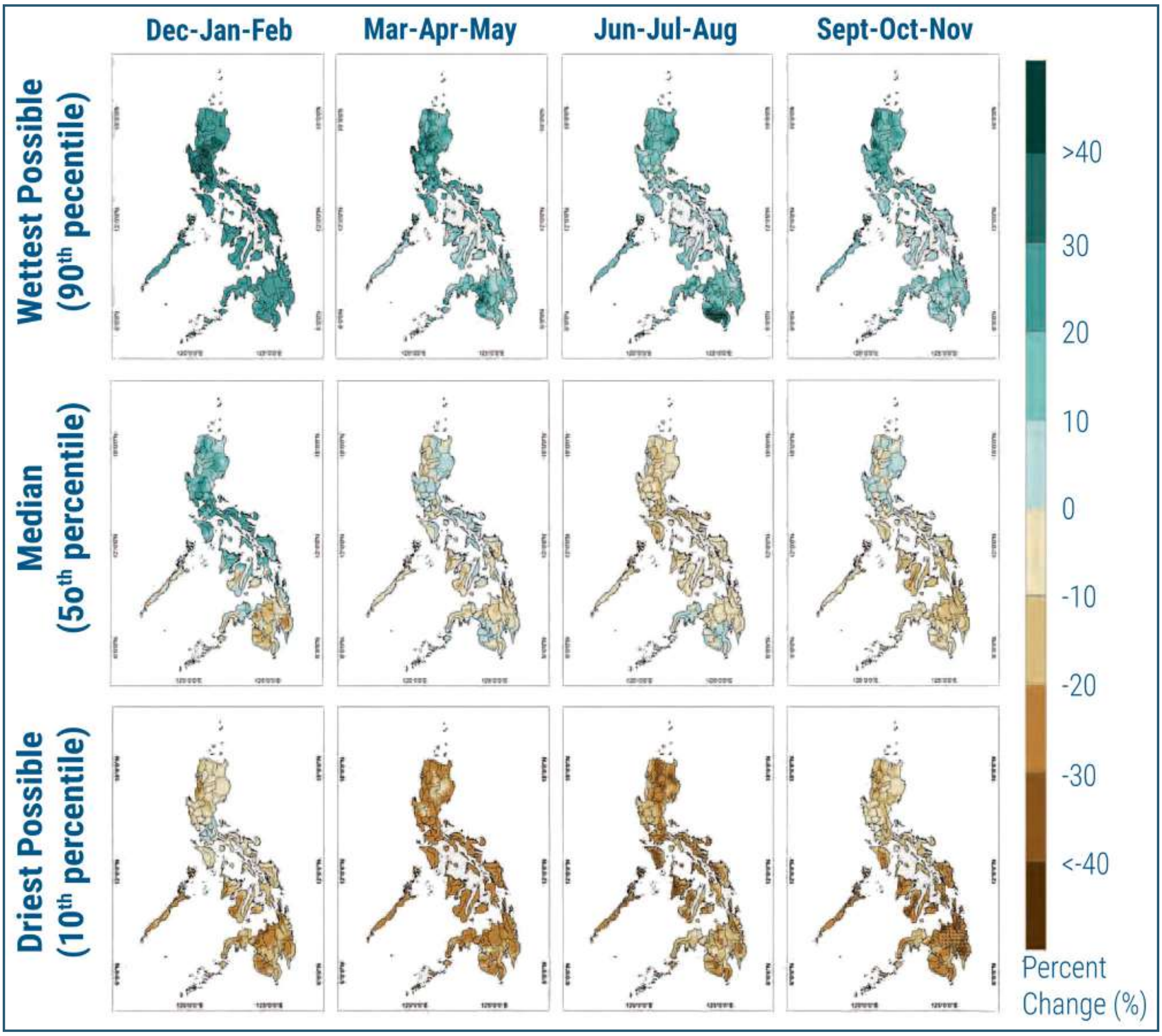


Figure 4.10_2. Projected Seasonal Change in Rainfall in the Philippines for the Mid-21st Century (2036-2065) Relative to the Baseline Period of 1971-2000.
Source: DOST-PAGASA (2018)

Other Environmental Hazards

The Philippines is a disaster-prone country and periodically suffers from deadly typhoons, floods, earthquakes, volcano eruptions and other natural disasters. It was ranked third in terms of disaster risk index in 2018. Due to its geographical context, the highest risks posed to the country are those of earthquakes reported with 10 risk index (RI) points and tropical cyclones of 9.5 RI. These are followed by tsunamis with RI of 9.3, flood RI of 7.2, and drought RI of 4 (WEF 2018).

The Philippine Statistics Authority's Sustainable Development Goals (SDG) watch reported that the number of deaths attributed to disasters per 100,000 population in 2016 escalated from 0.08 to 0.24 within the two-year study period (PSA 2020d). In addition, natural disasters-caused incidents for a 10-year period has been reported to reach an average of 201 occurrences in the country (PSA 2014). These catastrophic events not only caused environmental damages but also continuously slowed down national economic growth as finances were mobilized for disaster recovery and rehabilitation. An average annual amount of 27.9 billion pesos was spent in the past years to fund recovery and rehabilitation from extreme natural events (PSA 2014).

In response the government developed the national disaster risk reduction (DRR) strategy following the Sendai Framework for Disaster Risk Reduction 2015-2030. This is also consistent with Goal 13 of the UN SDGs, which prompts global and local actions to combat climate change and its impacts by strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries (UN 2019). Science, Technology, and Innovation (STI) are needed in developing a robust response agenda for DRR (Figure 4.10_3). The contributions of STI in disaster risk reduction and climate change adaptation for better resilience and competitiveness need not be over- emphasized.

In 2017, the Department of Science and Technology developed STI-based mitigation strategies against disaster and climate change consisting of various technologies intended to improve the existing mitigation strategies and technologies of the country such as:

- Radar Stations
- Flood Forecasting and Warning System
- Improvement of Volcano and Earthquake Monitoring Systems
- Deployment of Early Warning Systems in Disaster-Prone Areas
- Real-Time Radiation Monitoring System

In addition, the e-ASIA Joint Research Program consisting of the Development of Information Gathering and Utilization Systems Using Small Unmanned Airborne Vehicles (UAVs) for Disaster Risk Assessment, Monitoring, and Response for observation and monitoring systems was also launched.

Likewise, STI-based hazard and risk assessment tools are being used such as:

- Earthquake and Volcanic Hazard Mapping
- Specific Earthquake Ground-Motion to Help Enhance the Seismic Resiliency of Residential and Medium-to High Rise Buildings
- Improved Hydro-Meteorological Modules for Rapid Earthquake Damage Assessment System
- Hazard and Risk Assessment Tool for Mainstreaming DRR in Local Development Planning and the Phil-Light Detection and Ranging Technology Program

The disaster knowledge diffusion is promoted through the following:

- Hazard and Risk Information Through Web Applications
- Hydro-Met Information, Risk Assessment, and Inter-Linkages of Advisories
- Philippine Atmospheric, Geophysical, and Astronomical Services Administration Unified Meteorological Information System
- Development of Web-based Southeast Asia Climate Diagnostics and Monitoring

Terrestrial Ecosystems Use

In 1961, the number of people per sq km in the Philippines was just below 100 per sq km and increased to more than 350 per sq km in 2018 (World Bank 2020c). This is way above the global average of 59 per sq km. By virtue of the projected increase in the country's population in the next two decades, the population density per sq km is expected to put more pressure on our land resources. Urban areas like Metro Manila will expand up to the 2050s giving rise to natural habitat fragmentation (NEDA 2018).

Assuming that there will be no significant change in the legal framework for land use planning, development, and governance, the pressure on agriculture from the likely expansion of urban and infrastructure development could also increase. This in turn could add to the pressure of agriculture on forests and other natural ecosystems that will likely also increase the demand for food, fiber, and energy. Greater land degradation due to inefficient land use allocation and planning, unregulated land conversion, and climate change is likely, and could further compound the pressure on land availability and the integrity of natural ecosystems and prime agricultural land. Extreme rainfall events, floods, storm surges, prolonged droughts, and sea-level rise are also likely to worsen and could exacerbate ongoing land degradation processes in many areas of the country.

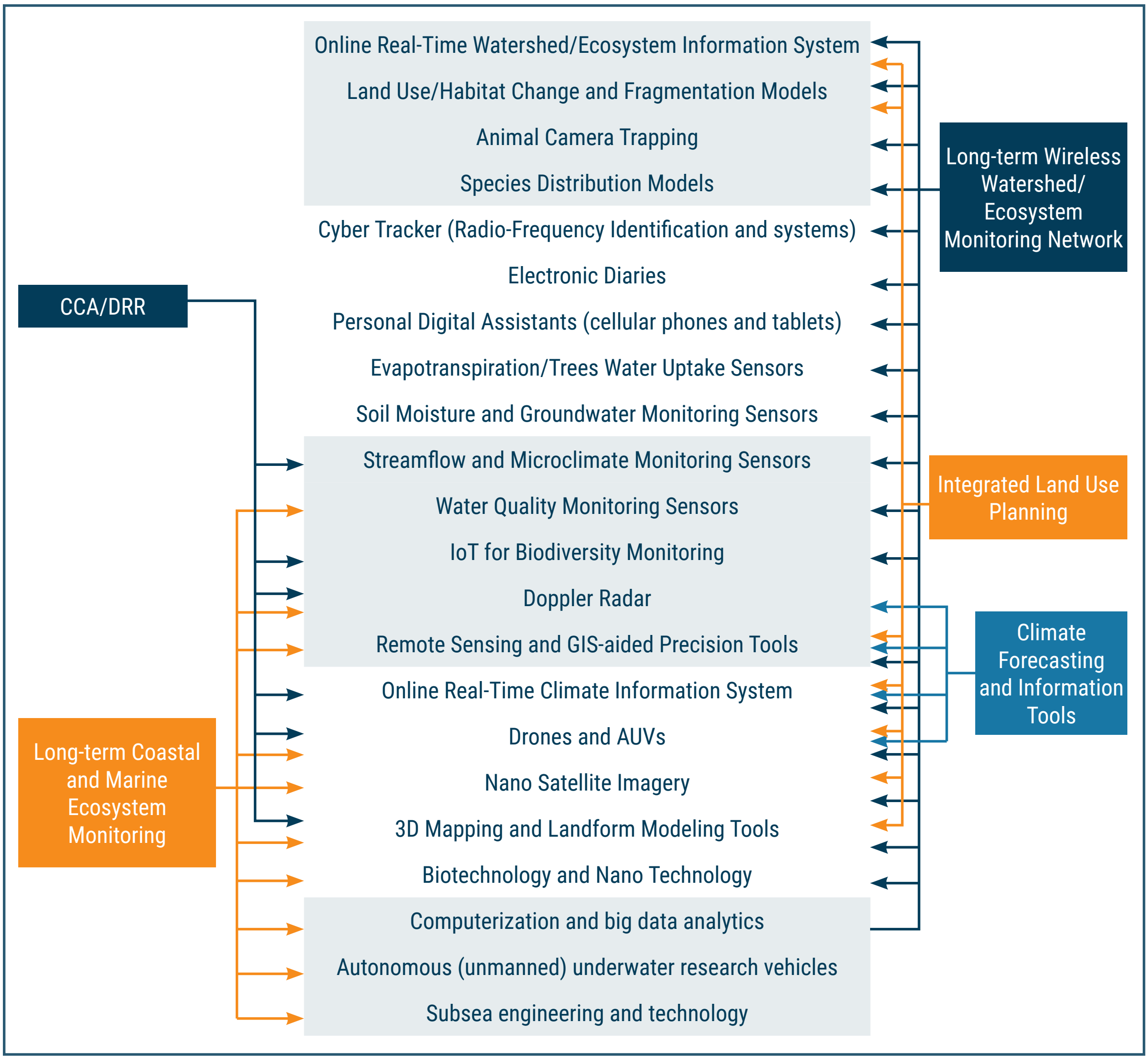


Figure 4.10_3. Summary of Science, Technology and Innovation for Sustainable Use, Climate Change Action and Disaster Risk Reduction for Terrestrial, and Coastal and Marine Ecosystems.
Note: CCA/DRR - Climate Change Action and Disaster Risk Reduction

Forests/Watersheds. The country's forest cover has dipped from a high of 10.9 M ha in 1970 to a low of 5.4 M ha in 2000 but, by 2005, forest cover started to increase though inconsistently until 2015 (see Section 1.5.1). This is largely due to the National Greening Program (NGP), logging restrictions, and forest protection programs. However, the increase in forest cover is hampered by the uneven success of these initiatives. Not all NGP areas have been successful, and there are areas where the continued loss of forest cover has negated gains in other areas (Perez et al. 2020). The increase of forest cover in our country could be accelerated if the implementation of these various government programs is strengthened through S&T and by the removal of policy barriers to private sector investment in forest plantation development.

Watersheds are of critical importance for purposes of protecting vital sources of water supply for irrigation, domestic and other uses, and biodiversity conservation (please see Section 1.5.1). Land use and land cover change is considered the most influential driver of watershed degradation in the country. The many laws and regulations (Presidential Decrees no. 112, 1413 and 2036, Proclamations no. 548, 505, 599, 573, 739 and 1111) to protect the country's watersheds notwithstanding, many watersheds have been degraded due to expansion of agriculture that lead to reduction of forest cover.

Thus, many of our watersheds continue to lose forest cover even though some watersheds had forest cover gains. This trend could persist into the coming decades if the current weaknesses in the enforcement of relevant laws and regulations, land use planning and development, governance, and science and policy interface are not addressed.

Agricultural Lands/Ecosystems. Agricultural areas are likely to expand to meet the increase in the demands for food, fiber, energy, and other products as the population grows. Expansion of agricultural areas will most likely cause further encroachment into forests and other natural ecosystems, and increase the use of marginal lands (i.e., grasslands, brushlands, and open areas) as can be inferred from the current trends of land use change in priority watersheds in the country. Urban expansion especially in Metro Manila and other major urban centers are likely to accelerate in the next two or more decades. In Metro Manila, the urban areas are projected to double in the 2050s (NEDA 2018) with expansion likely moving towards agricultural areas and natural ecosystems. This can escalate the already serious problems of natural habitat fragmentation, loss of biodiversity and ecosystem services, soil and water degradation, and mounting disaster and public health risks associated with climate change (see Section 1.6 and Section 2.2). The productivity of agricultural lands is also likely to decrease further due to water scarcity and prolonged dry periods, as well as from excessive soil loss due to climate change.

Soil degradation in the Philippines is intricately tied to land use and land use practices (see Section 1.6 and 2.2). Key soil problems in the country including the loss of soil organic carbon, acidity, nutrient loss, soil biodiversity loss, compaction and soil sealing are likely to worsen in the next decades unless weaknesses in land use management as discussed in the section above will be significantly resolved.

Unregulated land use change, expansion of agriculture in hilly lands and forest lands, expansion of infrastructure and urban development into agricultural lands, excessive cultivation and use of inorganic farm inputs, and overgrazing need to be addressed. Landscape-based land use planning, strict enforcement of land development controls and regulations, practice of sustainable agriculture and sustainable forest management will be imperative in promoting the sustainability of soil resources in the country and minimizing the adverse socioeconomic, environmental, and ecological impacts of soil degradation.

Coastal and Marine Resources

The Philippines, which is part of the Western Equatorial Pacific (WEP) region, is projected to experience locally prolonged drought and intense episodic rainfall with an increase in variability. The average percentage change in seasonal mean precipitation may reach 30% to 40%. Storms will become more intense, but the frequency will either decrease or remain unchanged (Anderson and Bausch 2006).

Significant increases in sea surface temperature (SST) (mean ocean surface change of up to 0.9–1.75°C under a high emission scenario) are expected. Global sea level rise (SLR) is projected at 4–12 cm per decade with the WEP region likely experiencing the higher of these global estimates. Global ocean pH is projected to decrease by 0.13 units by 2050.

The above impacts are likely to add pressure on top of the many anthropogenic pressures already bearing on marine ecosystems. Although the Philippines' high biodiversity can help reduce overall vulnerability, urgent actions are needed to build marine resiliency. Prolonged warming could disrupt reproduction cycles of target species. Recruitment failures for the less mobile species are also likely. A study of waters surrounding the Philippines mostly show a decrease of 6%–50% with the southern part being more drastically affected. Only the areas that are known to be upwelling sites seem to fare well such as the area off the Bicol shelf or the sub-surface upwelling site west of Luzon. An analysis of Philippine historical data showed that previous episodic warming has been observed to be more severe for the waters facing the Pacific, the north-northwest Philippines and the Kalayaan Island Group (KIG). These episodes caused the massive coral bleaching event documented in 1998.

Extreme rainfall due to storm events over a denuded watershed can lead to sedimentation, one of the highest stressors to the marine coastal environment. Persistent seagrass burial due to sedimentation of two cm to 19.5 cm has been seen to result in 50% shoot mortality and most likely lead to regression and complete destruction of the seagrass meadow.

The western boundary of the Pacific Ocean is one of the regions already experiencing relatively higher SLR than the global average. This makes the Philippines vulnerable to the combined hazards of SLR and storm surge. In the Western Pacific and Southeast Asian region, rates of SLR are about three to four times higher than the global mean, reaching around 12 cm per decade. This could lead to a 10%–15% mangrove loss globally (Alongi 2008).

The main effect is on the establishment of mangrove propagules and seedling growth. Seedlings in general have been found to thrive better in lower saline environments (3–17 psu) during their first four to five months. Additionally, most of the country's highly populated cities and much of the economic productivity is located near the coast. Fishing communities of Cotabato City and the province of Bulacan are at highest risk since a significant portion of the coastal and low-land areas are shown to be annually flooded. The other areas of concern are the coastal municipalities and small low-lying islands of Sulu and Tawi-Tawi (BARMM), Camarines Sur (V), Negros Occidental and Iloilo (VI), Quezon (IV-A), and Pangasinan (I).

Global ocean acidification is projected to cause a decrease of pH by 0.13 units by 2030 and up to 0.3 units by 2100. This increase in bicarbonates results in a faster dissolution rate of calcified structures like shells and coral reefs. At the same time increase in bicarbonates lowers carbonate ion concentrations and makes it difficult for calcifying invertebrates to form hard structures.

There are studies however that show a positive increase in productivity for ocean species that can make use of bicarbonates in photosynthesis (e.g., seagrass) and those that do not form hard structures (e.g., jellyfish). Changes in the productivity of ocean species could impact on the major source of animal protein for many adult Filipinos that on the average require between 49g–57g per day. Fisheries and associated livelihoods provide income to more than 30 million Filipinos, who are highly vulnerable to the projected changes in climate and its impacts on the condition of marine ecosystems (Figure 4.10_4). The impacts are likely to be compounded by the prevalence of high poverty incidence in farming and fishing communities (PSA 2017).

Scientific and technological advances are expected to play a crucial role in ocean-based economic activities. Among these are:

- innovations in advanced materials
- subsea engineering and technology
- sensors and imaging
- satellite technologies
- computerization and big data analytics
- autonomous systems
- biotechnology and nanotechnology

Every sector of the ocean economy/blue economy stands to be affected by these technological advances (See Section 4.1).

Aside from technologies and processes essential for realizing the potentials of STI in helping address problems of a deteriorating ocean and for ensuring sustainable development as described in the section on Philippine blue economy (See Section 4.8), the transformation of ocean sciences needs "a new movement" as the UN General Assembly has called for a Decade of Ocean Science for Sustainable Development (2021–2030). The aim of "The Decade" is to bring together researchers and stakeholders from all relevant sectors to generate new scientific process/es to ensure a well-functioning, productive, resilient, and sustainable ocean and support the UN 2030 Agenda for Sustainable Development (Madin et al. 2019).

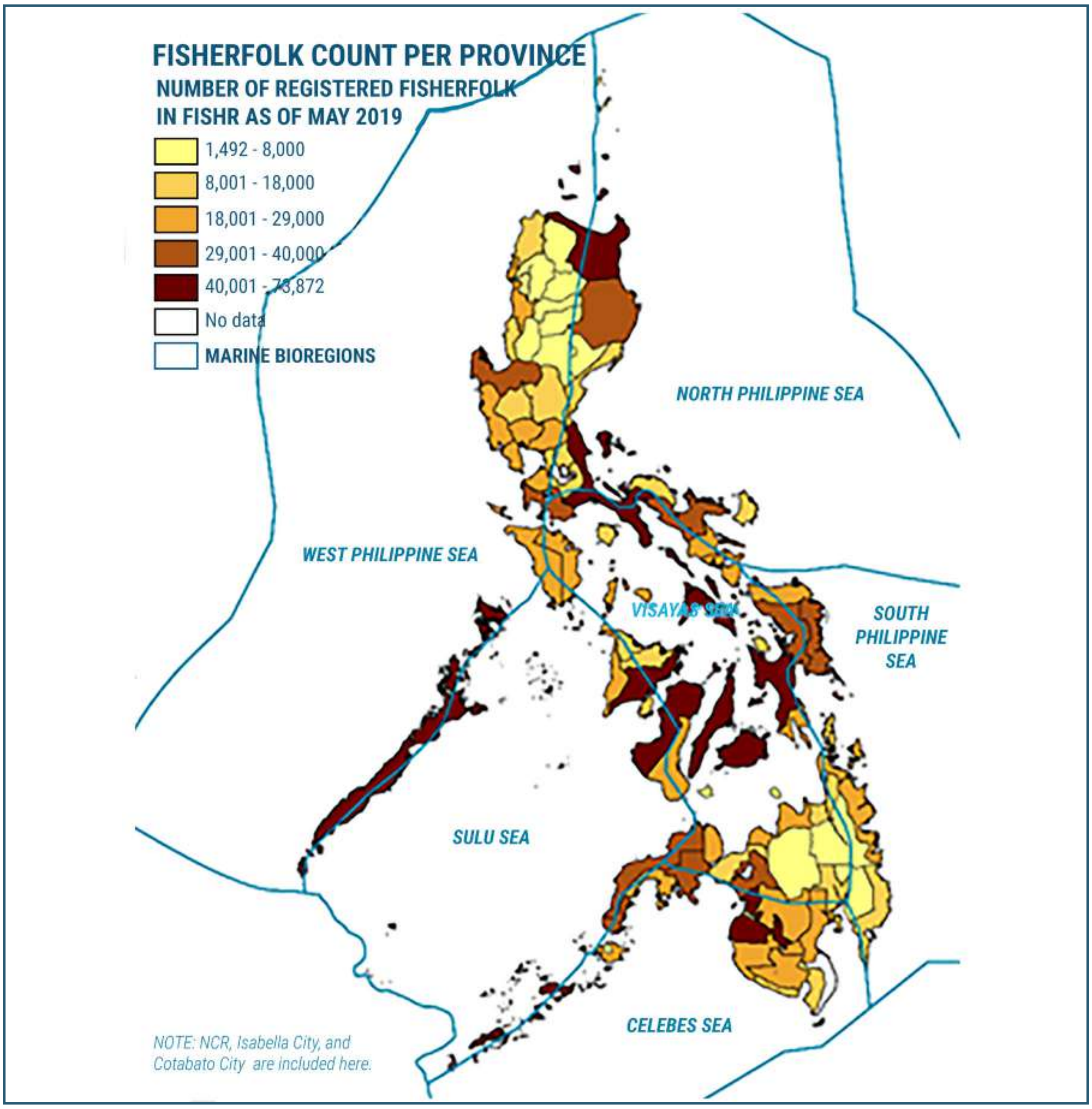


Figure 4.10_4. Fisherfolk Count per sq km of Municipal Waters
Source: BFAR (2019)

Biodiversity and Ecosystem Health

Consistent with the global outlook, the country's biodiversity and the services it provides will continue to deteriorate in the coming three decades and beyond if we continue with business as usual. Population growth will drive the conversion of, and encroachment into, natural ecosystems. The expansion of agriculture, infrastructure, urban development, and forest exploitation will cause further natural habitat fragmentation and biodiversity loss, as well as ecosystem services deterioration. Climate change will continue to alter the composition, structure, function, and resilience of many species and ecosystems. Many species will lose their habitats due to changing rainfall and temperature patterns that could lead to species displacement and loss. The timing of flowering and fruiting/reproduction in the terrestrial and aquatic habitats will change, with significant impacts on their ecology and the economy.

SECTION 4.11
SHELTER, TRANSPORTATION, AND OTHER INFRASTRUCTURE

Technologies for shelter, transportation, and other infrastructure in human settlements, communities, and cities will be increasingly crucial for our sustainable development through the coming decades and beyond. Technological advances show great promise in enabling the country to not just mitigate the effects of crises and disasters but also to prepare for them as best as possible. In this regard, Shelter and Transportation are inextricably linked: the former may be viewed as hubs and the latter as spokes in a human-settlement network and addressing the needs of one also supplements and complements the needs of the other.

Shelter in its most inclusive sense is any structure that is built for human occupancy and in support of the needs of a community—notably for housing and residence, emergency refuge, healthcare, education, governance, food storage or preparation, commerce, manufacturing, and so on (Pacheco 2020). On the other hand, transportation includes both the intra-community and inter-community mobility of people, goods, and services especially in an maritime and archipelagic environment.

As we have seen in Sections 2.5 and 3.2 of this Foresight, the development of Philippine shelter and transportation is one of fits and starts, with numerous plans seen over the years but little in the way of completion and follow-through. However, there is yet hope: as we endeavor to show in this section, the appropriate technology and innovation will be fundamental not just in defining shelter and transportation themselves, but also in how these are utilized and adapted for future needs.

Moreover, making communities and human settlements—as well as their interconnection by way of transportation—inclusive, safe, resilient, and sustainable is key to meeting the Philippines' own AmBisyon Natin 2040 plan as well as the United Nation (UN) Sustainable Development Goal (SDG) 11-"Sustainable Cities and Communities."

Shelter

There is an immediate need to provide safe, sustainable, and resilient shelters, given the country's extreme susceptibility to natural hazards. According to the World Risk Index, the Philippines is the ninth most at-risk country to the effects of natural hazards (Radtke and Weller 2019). In Metro Manila alone, it is estimated that a magnitude 7.2 earthquake may result in the complete collapse of over 88 million sq m of floor area and PHP 2.5 trillion in economic losses (Bautista et al. 2013).

The effects of hydrometeorological hazards are also a major concern. For instance, Tropical Cyclone Haiyan in 2013 left over a million houses destroyed or damaged and 4 million people homeless (NDRRMC 2014). Meanwhile, the current housing backlog stands at 3.9 million units and will balloon to 6.5 million units by 2030 (Padojinog et al. 2016). Thus, we need to sustain an annual production of 346,000 units per year in order to meet the demand. With other shelter types as well—such as schools, hospitals, evacuation centers, transportation hubs, and others—backlogs are identified and bigger future demands are projected.

Recent studies as of this writing have also revealed key insights into the development of shelters and other infrastructure in the Philippines. Typhoon Haiyan was a main point of discussion, considering the extent of its impact and the response thereto in the years that followed. Hernandez et al. (2015), Sanada et al. (2015), Youngkyou (2015), and Ravina et al. (2018) highlighted the need for better construction materials and techniques, informed by the hard-earned craftsmanship skills, indigenous knowhow, and local innovation born from the on-the-ground experiences of disaster-stricken communities. Opdyke et al. (2018a and 2018b) and Curato (2018), noted the importance of logistics, training, local experience, and informed governance in preparing and responding to disasters. As we show later in this section, both the effective use of current technology and the appropriate adoption of upcoming technology developments will be valuable in all these areas, as well as in seeking to address other concerns such as minimizing carbon footprints and efficient waste management. Quality as well as quantity of houses, structures, and buildings must be addressed by updated building laws, regulations, and standards (Pacheco 2020).

Transportation

Transportation presents endless challenges in terms of linking the islands of the archipelago, the urban-rural communities and, in different ways, providing mobility within urban centers like Metro Manila, Metro Cebu, and Metro Davao. Urban transport problems include road and public transport congestion; long average trip lengths; lack of decent public transportation options; lagging public and active transport infrastructure; and high levels of air and noise pollution (Gaabucayan-Napalang 2016).

Though numerous master plans have been developed, non-implementation and lack of coordination in government have led to further exacerbation of these problems (JICA and ALMEC 2019). A continued focus on private car-centric solutions is especially frustrating considering that, in Metro Manila alone, only 20% of trips are made using private modes—e.g., motorcycle, cars, taxis, etc.—while 50% are done through public modes, with the remaining 30% done by walking (JICA 2014). There has also been little discussion regarding the urban-rural linkages, and the problems and solutions that arise from these. Some of the infrastructure shortcomings include poor—and sometimes altogether missing—road networks, and the lack of public transport to some areas due to low economic viability (Wear 2009).

Recent transportation studies on optimization or efficiency have looked at various possible solutions to these problems, from rideshare and autonomous vehicles to using data science and information technology (IT) to better understand accidents and hazards (Opiso and Puno 2015; Verzosa and Miles 2016; Ubando et al. 2019; Lopez et al. 2020). More studies are needed on combinations of road, rail, water, and air transportation modes, especially considering the archipelagic setting and maritime nature of the country, and the national aspiration to balance urban and rural development.

Others

Another area of infrastructure in communities and cities is solid waste management, which ideally follows the principles of a circular economy: the community should be able to process its own solid waste by reduction, reuse, and recycling. The Philippine Development Plan 2017–2022 specifically highlighted the demand for, and continuing inadequacy of, solid waste management as a fundamental social infrastructure (NEDA 2017). As of 2017 alone, the country's total solid waste generation was estimated at 40,000 tons per day, yet only 37% of local government units were in compliance with RA 9003 or the Ecological Solid Waste Management Act of 2000. Hazardous wastes also remain largely unchecked, with insufficient data to develop plans, policies, programs, and projects to handle their management and proper disposal (NEDA 2017).

As explained below, technological advances in both shelter and transportation may also be linked or coordinated with technologies for waste management.

2050 and Beyond

Contemplating the future of shelter and transport in the country necessitates a continuous revisiting—and, if necessary, a full revision—of our understanding of these sectors as our communities change and grow. We must be careful, for instance, not to take city expansion as the only path to progress; other solutions may present themselves if we only allow ourselves to rethink our notions of urbanization.

Secure home ownership and good transport facilities are minimum basic needs that are also fundamental to what Filipinos perceive as “maginhawang buhay” or a comfortable life, as discussed in AmBisyon Natin 2040, the 1987 Philippine Constitution, RA 8425, and the Philippine Development Plans and which still remain relevant within the extended 30-year timeframe of this Foresight. AmBisyon Natin 2040, in particular, identifies eight priority sectors—all of which require shelter and transportation infrastructure:

- Housing and Urban Development
- Connectivity
- Manufacturing
- Education Services
- Tourism and Allied Services
- Agriculture
- Health and Wellness Services
- Financial Services

Specific to housing, for the average Filipino, house rental is a large and continuing expense that eats into the budget for other daily needs. Thus, access to decent shelter relates closely to the “panatag na buhay” secure life that we all aspire to through AmBisyon Natin 2040, the minimum basic needs under RA 8425, and this Foresight: to have enough resources to cover day-to-day needs, peace and security, long and healthy lives, and a comfortable retirement. Better housing specifically, or better shelter generally, also provides peace and security with family and local community, and a comfortable space to settle in upon retirement—a growing concern, as the population shifts to a bigger proportion of senior citizens.

Better transportation facilities are also essential to this vision of a comfortable life. Better facilities lead to faster and more convenient transport of people and goods, which is the ultimate goal of transportation. Improved transportation facilitates better work-life balance; more time for family and friends; freedom from hunger, poverty, and homelessness; mobility to travel for vacation; peace and security; a long and healthy life; and comfortable retirement—all of which are enshrined in the 1987 Philippine Constitution, RA No. 8425, the Philippine Development Plans, and AmBisyon Natin 2040.

Community and city planning should wisely integrate the components of shelter and transportation in such ways that travel demand itself is minimized while the mixed use of shelters and of land are carefully planned and monitored—or, in the case of catastrophic events, the communities and cities are better replanned and built back.

Suggested Technologies in Anticipation of Future Needs

The UN highlights five emerging technology clusters that are crucial to reaching its SDGs: digital technologies, nanotechnologies, biotechnologies, neuro-technologies, and green—or, rather, clean—technologies (UN 2016b). We adopt the term “clean technology” over “green technology” because of the more encompassing nature of the former. Here we define clean technology as any innovative technology, process, product, or service that uses energy or resources in a sustainable manner and produces no or the least negative impacts on society, environment, and economy (Uriarte 2020).

Many of the technologies that we see in the near and far horizon may be associated with one or more of the above clusters (Table 4.11.3_1). We shall endeavor to explain the various technological intervention in the following:

> **Shelter.** Innovations as far afield as nanotechnology and even biotechnology have had a profound impact on the design and construction of shelters. Advances in these fields have led to the development of new construction materials, e.g., aerogels for use as insulation; window coatings and building cladding that automatically adjust to changing weather and climes; clean bioluminescent lighting; and high-strength, fire-resistant, and sustainably-sourced wood structures. These new materials could result in houses and buildings that are cheaper yet sturdier, and more energy-efficient than current technologies allow.
>
> 3D printing, robotics, and artificial intelligence (AI) could then be used to automate the assembly of these materials into shelters. Robotics will play a large part in construction, particularly in highly repetitive and accident-prone activities to minimize danger to laborers. AI-enabled drones, or unmanned aerial vehicles, could also be used in tandem with robots in actual construction processes. These automated technologies will be particularly useful when structures need to be constructed rapidly, as in disaster-stricken areas.
>
> Once set up, the structures can be continually monitored and assessed via AI and information and communications technology (ICT) for integrity and adequacy in providing for the needs of their occupants. Automated tools can be used to monitor the impact of infrastructure development, economic cost, and communities’ overall well-being. For example, wireless sensors scattered through a community could monitor temperature and water levels, while adaptive AI algorithms optimize resource usage and compliance with pre-set parameters. Proper data science and AI-enabled technology can make all of these possible timely interventions while minimizing human error and bias.

At all stages of design and construction, virtual and augmented reality (VR and AR) technology will enable policymakers and engineers to better understand the impacts of infrastructure projects while—and even well before—these are implemented. VR and AR can also be used to simulate peoples' responses in emergency situations, enabling us to enhance disaster evacuation plans and design drills.

The convergence of all these technologies could potentially result in more democratic access to affordable housing, fewer street crimes, more productive personal time, and an overall healthier and safer living environment.

Transportation. Innovations in nanotechnology and biotechnology have likewise had a profound effect on transportation. This is largely in the way of biofuels, or fuels sourced from organic materials such as corn and sugarcane; and lightweight yet energy-efficient batteries. Electric cars, boats, and even airplanes are feasible mainly through the development of such power sources, which impact these vehicles' carbon footprint and operational range.

However, nanotechnology, biotechnology, and clean technology also come together in the design and construction of the vehicles themselves: new materials that are lightweight complement their power sources' limitations. Materials technology also impacts vehicle support infrastructure, such as charging stations, which must be put up at strategic locations across the country to help reduce the fossil fuel dependence and reduce greenhouse gas emissions in the country.

Some transport solutions currently have limited applications in more developed nations, at least for now, but will drastically revolutionize transportation in the near future: these include magnetic levitation (maglev) trains; autonomous or self-driving vehicles; and even flying cars. How the Philippines manages its communities in the next 30 years, specifically in terms of shelter and transportation, will be a major factor in the possible local adaptation of any of these solutions. Ultimately, these future modes of travel should allow consistently high average speeds, enabling public and private commuters to live farther away from their destinations. This will improve productivity, make travel less stressful and more healthful, and enable wider access to reliable transportation as a basic human right.

Meanwhile, autonomous vehicle technology—driven by advancements in digital and neurotechnologies—has been maturing steadily in recent years, demonstrating an improved ability to avoid accidents as well as improved better energy efficiency. Self-driving automobiles will come into their own in conjunction with beacon technology to help synchronize traffic flow on increasingly congested roads.

Table 4.11.3_1. Product/System/Technology on the Horizon for Shelter, Transportation, and Other Infrastructure

Product/system/technology	Technology Clusters (as defined in SDG 11)				
	Digital Tech	Nanotech	Biotech	Neurotech	Clean/ Green Tech
3D printing or additive manufacturing of materials	●	●	●		●
Active energy-response building cladding or window technology, including electrochromics and thermochromics	●	●	●		●
Aerogel insulation		●	●		●
AI tools to monitor impact of infrastructure development to economic cost and well-being of communities	●			●	●
Automatic small-freight transportation system using underground spaces and building conduits	●			●	●
Autonomous vehicles	●	●		●	●
Battery-free wireless communications	●	●	●		●
Biofuels		●	●		●
Bioluminescent lighting		●	●		●
Building information modelling systems	●			●	●
Carbon conversion, sequestration, storage in building materials		●			●
Carbon fiber bodies		●	●		●
Decision-making software to support the optimization of building maintenance	●			●	
Demand-responsive domestic appliances	●			●	●
Digital floor plan-based automatic high-rise building construction robots	●				
Energy self-sufficient megabuilding design construction technology	●				●
Flying cars	●	●		●	●
Food storage, packaging, and distribution facilities	●	●	●	●	
Fuel cells		●	●		●
Fuel efficient and environment-friendly engines			●		●
High-speed vertical-horizontal 3D track system in high-rise-buildings-underground spaces	●			●	
High-strength wood components and fire-resistant wood structures for the construction of low- and high-rise wooden buildings, such as office buildings	●			●	
Household waste collection/transportation/categorization system for recycling or energy-recovery	●	●	●	●	●
Hybrid electric vehicles		●	●		●
Hyperloop transport	●	●		●	●
Hypersonic airplanes	●	●			●
Indoor and outdoor operable unmanned vehicle technology				●	●
Internet of Things, Internet of Everything	●	●	●	●	●
Maglev trains	●	●			●
Micro-hydro system using rainwater in high-rise buildings		●	●		●
Modularization-based LEGO-type one-day housing construction technology	●	●			●
Multiple biometric recognition			●	●	
Nano-energy generator		●	●		●
Nanotech-improved LED Lightbulbs		●			●

Table 4.11.3_1. Continued

Product/system/technology	Technology Clusters (as defined in SDG 11)				
	Digital Tech	Nanotech	Biotech	Neurotech	Clean/ Green Tech
Natural bioremediation and phytoremediation in and around buildings			●		●
Passenger health monitoring systems	●	●	●	●	
Photovoltaic cell		●			●
Pressure and motion sensors		●			
Quantum dot vision windows		●			●
Rainwater harvesting		●			●
Real-time continuous disaster-monitoring technology using remote sensing information of multiple satellites	●			●	
RFID tagging and tracking systems	●			●	
Robot inspection technology to inspect buildings or infrastructures that are more dangerous or constly for humasn to inspect	●	●	●		
Safety communications systems	●			●	
Seismic damage prediction systems	●				
Shelters and emergency facilities	●	●	●	●	●
Smart grid energy monitoring, networking, distribution	●			●	
Smart paint and material for self-diagnosis of facility damage and measurement of deterioration		●	●		●
Smart water monitoring	●	●		●	
Solar greywater disinfection		●	●		●
Structural health monitoring; sensors in buildings		●		●	●
Traffic control systems	●			●	●
Unmanned low-altitude aircraft for the surveillance of territorial waters, disaster monitoring, and rescue support	●	●	●	●	
Vertical farming		●	●		●
Wastewater nutrient recovery			●		●

Digital and neuro technologies are integral to many other current innovations that fall under the umbrella of Intelligent Transport Systems (ITS)—basically, the application of ICT to aggregate large data sets to inform the operations of various transportation systems, from real-time traffic management to electronic payment and scheduling systems. ITS can be closely tied to transportation and infrastructure. It could, for example, be used to inform travelers of flood conditions ahead of them or to help policymakers make more informed decisions based on the air, noise, and traffic quality in their locality. ITS can also be used to monitor the physical condition of transportation infrastructure in real time, alerting agencies if and when upkeep is needed, as well as for accident monitoring and prevention.

ICT could also be used to promote the use of public and active modes of transportation. For public transportation, applications include scheduling optimization, improved demand to capacity ratio, and better fuel efficiency. As for active modes such as cycling and walking, better ICT could provide route optimization not only in terms of distance but also in terms of air quality and noise. Monitoring the condition of infrastructure such as bike lanes and walk paths, paired with good information dissemination systems such as mobile apps, will also increase the use of these transport modes. Bike-sharing initiatives are also only possible with good ICT infrastructure and better demand forecasting to improve usage rates.

Transport planning and adjacent concerns—traffic management, road safety, greenhouse emissions, etc.—would also improve when paired with different technology-dependent applications. Aside from the improved forecasting afforded by better data collection discussed earlier, the use of Geographic Information System (GIS) to analyze service areas of different transportation infrastructure such as public transport terminals. The analysis of residential distribution compared with data regarding work and study locations through GIS would allow planners to locate these transportation terminals and identify public transport routes that would capture a larger ridership.

These concepts can be seen in the principles of transit-oriented development, wherein land use planning is based on the available infrastructure. However, this is not feasible for already developed areas such as Metro Manila. Hence, there is a need to adapt the planning of transport modes to these developments—a development-oriented transit planning.

These innovations are only possible with the proper support infrastructure in place, such as sensors, cameras, gantries, and data management centers. Aside from the shelter and transportation infrastructure themselves, investment in ICT infrastructure is vital for the country to achieve the vision set forth.

Others. Many of the previously listed technologies for shelter and transportation could also be used for the management and safe disposal of both solid and hazardous waste. Nanotechnology, robotics, and 3D printing, for example, could be deployed to erect containment facilities without risking human exposure to these wastes. ICT and AI for shelter and transportation needs can also be adapted to specifically monitor and address waste production and disposal.

Convergence underlies many of these technologies on various levels, underscoring the potential for cooperation between various sectors. For example, in terms of SDG 11 clusters, digital and biotechnology are coming together, since computing technologies take inspiration from biological processes. Meanwhile, the Internet of Things is enabling better interactivity and coordination of the technologies between our vehicles and homes. For example, in conjunction with satellite data and remote sensors, one's mobile phone could provide updates on commuter traffic at bus stops and train stations or provide farmers real-time updates on crop health. In terms of circular economies, various technologies for shelter and solid waste management could enable more clean and efficient waste-handling.

Policies and Futures

That the above emergent or emerging technologies encompass shelter and transportation as well as solid waste management attests to the interrelatedness and interconnectivity of these sectors. The development and appropriate adoption of technologies in these and all other sectors are ultimately also dependent on technologies for the gathering and analysis of data and information, both extensively and intensively, i.e., data science. Ultimately, access to information is fundamental to the development of these technologies in anticipation of future needs, including the establishment of smart communities. Not only should everyone be assured of decent minimum bandwidth access—at least enough to adequately communicate online—but they should also be assured of access to critical information in a timely manner so they can make better-informed decisions. In this way, digital technology powers the other technology clusters: nanotechnology, biotechnology, neuro-technology, and clean technology.

In Table 4.11.4_1, we consider the following as facets of the Philippines' aspirations: Sustainability, Resilience, Competitiveness, Inclusivity, and Human Development. We then look at how SDG 11 addresses these areas, with sample recommendations for policies that should be implemented immediately and/or into the medium- and long-term future. It must be stressed, however, that a regular iterative process of reassessment and readjustment is necessary so that policies and targets remain aligned with the needs and aspirations of Philippine communities as we journey to the year 2050.

Many of the challenges and opportunities for innovation are at the regional and local levels, where the full range of science, technology, innovation, craftsmanship, and skills outlined and aspired to in this Foresight can best be brought to bear in service of even the most far-flung communities, households, and individuals. Upcoming innovations in shelter, transportation, solid waste management, and other areas discussed elsewhere in this Foresight will play increasingly crucial roles not only in improving Filipinos' lives in the near and long term, but also in building back better after any future catastrophic events.

Table 4.11.4_1. Policies and Futures for Shelter, Transportation, and Other Infrastructure with Reference to the SDGs

Levels of Urgency of Policy Intervention	Sustainability	Resilience	Competitiveness	Inclusivity	Human Development
Relevant SDG11 Indicators and Goals	(11.6) REDUCE THE ENVIRONMENTAL IMPACT OF CITIES: By 2030, reduce the adverse per capita environmental impact of cities, paying special attention to air quality and municipal and other waste management (11.2) AFFORDABLE AND SUSTAINABLE TRANSPORT SYSTEMS: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improve road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons	(11.5) REDUCE THE ADVERSE EFFECTS OF NATURAL DISASTERS: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	(11.A) STRONG NATIONAL AND REGIONAL DEVELOPMENT PLANNING: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning (11.B) IMPLEMENT POLICIES FOR INCLUSION, RESOURCE EFFICIENCY, AND DISASTER RISK REDUCTION: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels (11.C) SUPPORT LEAST DEVELOPED COUNTRIES IN SUSTAINABLE AND RESILIENT BUILDING: Support least developed countries, through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials	(11.3) INCLUSIVE AND SUSTAINABLE URBANIZATION: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries (11.7) PROVIDE ACCESS TO SAFE AND INCLUSIVE GREEN AND PUBLIC SPACES: By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	(11.1) SAFE AND AFFORDABLE HOUSING: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums (11.4) PROTECT THE WORLD'S CULTURAL AND NATURAL HERITAGE: Strengthen efforts to protect and safeguard the world's cultural and natural heritage
Immediate	**Policies:** Mandating the construction of inclusive and accessible infrastructure and transport facilities, e.g., building codes that require access ramps, safety rails, etc. Mandating proper waste handling at all community levels, e.g., segregation schemes, recycling facilities, etc. **Metrics:** (11.2.1) Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities (11.6.1) Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities	**Policies:** To safely evacuate and transport communities to safe areas and disaster shelters. To develop storm surge barriers and closure dams for flood-prone areas. To improve the quality of shelter materials and the craftmanship of shelters **Metrics:** (11.5.1) Number of deaths, missing persons and persons directly affected by disaster per 100,000 people	**Policies:** Provide for consultation with, and education of, local communities regarding knowledge and skills born from on-the-ground experiences of disaster-stricken communities. **Metrics:** (11.B.1) Country adopts and implements national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015-2030	**Policies:** Implementing technologies that reduce accidents and increase public safety, e.g., autonomous vehicles and monitoring systems Policies that consider lessening or eliminating peoples' travel time, e.g. work-from-home setups, flexi-time offices, work-home clusters, etc. **Metrics:** (11.3.2) proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically (11.7.2) Proportion of persons who are victims of physical or sexual harassment, by sex, age, disability status and place of occurrence, in the previous 12 months	**Policies:** Develop low-cost resilient shelters to meet housing demand in highly populated and/or disaster-stricken areas. Allocate strategic spaces for upgraded housing and cultural community activities. **Metrics:** (11.1.1) The proportion of urban population living in slums, informal settlements or inadequate housing

Table 4.11.4_1. Continued

Levels of Urgency of Policy Intervention	Sustainability	Resilience	Competitiveness	Inclusivity	Human Development
Medium-term	**Policies:** To adopt technologies which have lesser environmental impact, e.g., electric vehicles and clean fuels. **Metrics:** (11.6.2) Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)		**Policies:** Reserach funding for the design and construction of shelters, and for disaster response plans **Metrics:** (11.A.1) Proportion of population living in cities that implement urban and regional development plans integrating population projections and resource needs, by size of city	**Policies:** Policies that provide for the sufficient allocation of green communal spaces within urbanized areas, e.g., city parks and walkways. **Metrics:** (11.7.1) Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities	
Long-term		**Policies:** To categorize and define areas which are frequently stricken by disasters Provide for the permanent relocation of communities from frequently disaster-stricken areas **Metrics:** (11.5.2) Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruption of basic services, attributed to disasters	**Policies:** Incentivise local government units to devise and adopt disaster response plans **Metrics:** (11.B.2) Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies (11.C.1) Proportion of financial support to the least developed countries that is allocated to the construction and retrofitting of sustainable, resilient and resource-efficient buildings utilizing local materials	**Policies:** Policies that position green spaces and clean technology as fundamental to long-term community growth and development, e.g., green cities and regional energy self sufficiency **Metrics:** (11.3.1) Ratio of land consumption rate to population growth rate	**Policies:** Incentivise the identification, preservation, and repurposing (where appropriate) of areas and infrastructure of high historical and/or cultural value Provide for technologies that can be used to preserve and propagate indigenous knowledge and other forms of intangible heritage **Metrics:** (11.4.1) Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage

SECTION 4.12
SPACE EXPLORATION

The Philippines initially participated in space technology primarily only through the use of data and equipment provided by other countries. Realizing the relatively short lifetime of satellites and the technological advances achieved in the development of space technology, many countries, including our neighbors, have started putting together their own space systems so as to be less dependent on data and facilities provided by other countries. Being an archipelagic and maritime nation, the Philippines has recently participated in this endeavor, through the initiative of the Department of Science and Technology and succeeding efforts of the new Philippine Space Agency (PhilSA).

In the Space Economy report published by the Space Foundation USA, the global space economy was valued at USD423.80 billion in 2019 (Space Foundation 2020). Of this amount, about 79% or USD336.89 billion came from commercial space revenue and the remaining amount was government spending. According to a recent Australian Government report (Australian Government and Asia-Pacific Economic Cooperation 2019), the value of earth and marine observation (EMO) to the Philippines economy in 2019 was estimated at USD657 million. With targeted investments and collaboration, the economic contribution of EMO to the country's gross domestic product (GDP) is projected to grow to USD6.6 billion by 2030. For the Philippines to seize these opportunities in the global space economy and derive optimum economic value from upstream and downstream space science and technologyapplications (SSTA) activities, public and private sector investments and partnerships in space research and development (R&D), capacity-building and infrastructure need to be sustained. This includes support for establishment of enabling environment, i.e., relevant facilities that will nurture scientific innovation and operational requirements in SSTA.

Short-Term and Long-Term Goals in the Upstream and Downstream Developments in Space

- **S**purring scientific growth that fosters patriotism and accelerates national progress
- **P**romoting improved public access and resource-sharing for the utilization of spaceborne data, space-enabled services, and space-related facilities;
- **A**ccelerating the transfer and diffusion of space technologies throughout Philippine society towards developing a robust and vibrant local space economy
- **C**reating a coherent and unified strategy for the development, utilization, and promotion of SSTA in line with the Philippine Space Policy
- **E**nhancing the Philippines' official representation and contribution in the international space community for establishing cooperation.

Upstream Space Initiatives

For the upstream space segment, the goal is to realize and expand economic opportunities, e.g., GDP growth, job creation, inbound capital investments, as a direct result or spillover effect of the local innovations in space missions and satellite technologies. Fostering capabilities in the upstream segment enables influence in the standards that govern downstream operations and applications, such as end-user applications and requirements. Building space satellite payloads and buses equip us with the wherewithal to adapt to and anticipate evolving downstream requirements, thus the ability to customize solutions for existing and new downstream verticals.

Participating in the upstream value chain of space offers opportunities for local design, manufacturing and testing services that will help put us on a path of building stronger industries in aerospace, semiconductors, electronics, mechanical products and materials, among others. This, in turn, can lead to more high-value jobs that are useful across a wide range of modern industries.

In the near term, this initiative targets the development of a 100-150 kg class satellite in an industrial setting with the end-to-end participation of Filipino engineers and scientists, starting with the Mula multispectral Earth observation satellite in 2020. Inherent in this setup, therefore, is formal know-how transfer and retention for the country, which is leveraged to subsequently produce a pipeline of satellites with increasing local inputs. The supply, fabrication, and testing of subsystems in succeeding efforts to rebuild the satellite can be pursued domestically, which can spur local space industry development.

The upstream space segment also involves infrastructure such as rockets, and spaceports used to launch spacecraft into space orbit which also allows the launch of sophisticated satellites that are now being used to study the Earth and the Universe. The basic requirement for a space technology program is the capability to build rockets and be able to launch them. The Philippines has had a modest rocket program (the Santa Barbara Project) but this was classified and a trace of that capability is no longer available. It is now recognized that such a program should be revived as soon as ample funding to pursue such an endeavor is available. The roadmap for space development in the Philippines is shown in Figure 4.12_1.

Currently, the Philippines depends on other countries and windows of opportunities to be able to launch its satellite. The ability to be able to launch our own definitely has a lot of advantages and lies at the heart of our aspirations to be a space-faring nation. One advantage is the ability to build satellites at the desired technical specification without worrying about the restrictions and capability of available launch vehicles. We will also be able to control the trajectory and orbital parameters that fit the goals of the mission. Furthermore, there are many military applications including the development of defense systems that can protect our cities from hostile attacks.

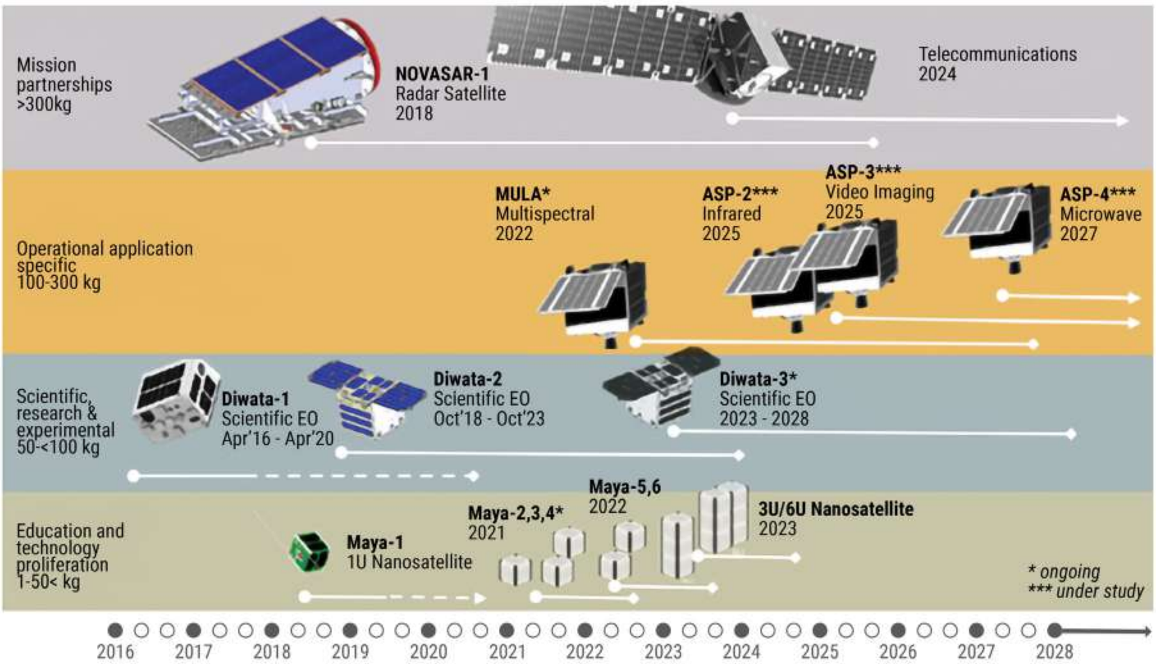


Figure 4.12_1. Near- to Medium-Term Capability Roadmap in Satellites and Upstream Space Development
Source: PhilSA (2020)

Downstream Space Initiatives

The Philippines is already an active user in the downstream space segment in terms of the data and services generated by satellites. Over the last few decades, satellite data became more accessible with key national space agencies (e.g., National Aeronautics and Space Administration, Japan Aerospace Exploration Agency, and European Space Agency) making their data freely available to the public and private companies (e.g., MAXAR, Planet) offering commercial data through paid subscription. We expect this trend to continue, and with the country's satellite development program generating its own, voluminous amounts of data are available for many different applications. Geospatial information from Earth observation satellites have been shown to be effective in supporting effective disaster risk reduction and management, agricultural crop monitoring and mapping, forestry management, land use and land change mapping, and maritime domain awareness, among other applications (Australian Government and the Asia-Pacific Economic Cooperation 2019).

The data can help enable better governance through evidence-based policies and their effective monitoring or assessment, which are crucial in alleviating challenges brought about by large scale crises such as the COVID-19 pandemic. Satellite images and other spaceborne data serve as tools that support timely planning, monitoring, and evaluation over large geographical areas.

In the near term, we will continue to support investments in capabilities for low-level access to satellite data, and the generation of higher-level, value-added data products. With the reversal of economic growth and increasing unemployment due to the impacts of the pandemic, addressing water and food security is at the forefront of the government's recovery program. In this regard, precision agriculture systems that make use of satellite data would help determine suitable areas for crops or commodities, especially in the regions where there is an influx of displaced populations from the metropolis.

Solutions that will increase farm productivity with fewer input resources and without further expansion of arable lands are also sought after. As for wild-catch fisheries, maps that delineate productive waters are invaluable in maximizing fishery catch and at the same time provide locations of key spawning areas that need to be protected to sustain the fishery industry (Klemas 2013). In addition to providing a sustainable food supply, there must be sufficient water for domestic, agriculture, and industry needs. To aid in water resources management, we can use satellite observations in monitoring precipitation, waterways, and aquifers.

Other priority areas include preparedness for natural hazards, climate change mitigation, and disaster response. In 2018, the country ranked 3rd among the most disaster-prone countries (Muller-Karger et al. 2018). We should exploit available satellite data to contribute to the concerted effort of minimizing damages to properties and loss of lives. The continuous degradation of our environment is also a cause of concern. Advanced satellite instruments can now monitor air and water quality, as well as changes in vegetation cover. Leveraging these capabilities, we can aid in the implementation of some key environmental programs such as the Manila Bay mandamus and the National Greening Program.

The realization of these goals is embodied in the initiatives of the PhilSA on "Mobilizing Space Data", which support the continued operation and expansion of local ground receiving stations, along with processing, archiving, and distribution systems through the Philippine Earth Data Resource Observation Center. With our ability to process satellite data, we can now routinely generate level 1 to level 3 analysis-ready data and value-added products that can be used for decision-making. The data processing workflows employing remote sensing, data science, machine learning or Artificial Intelligence (AI) are addressed through the institutionalization of the Remote Sensing and Data Science Help Desk project. A 3-tiered approach in data mobilization, as shown in Figure 4.12_2, outlines how satellite data products will be utilized by various agencies and integrated into their operations.

Figure 4.12_2. Near to Medium Term Capability Roadmap in Space Data Downstream Utilization and Development

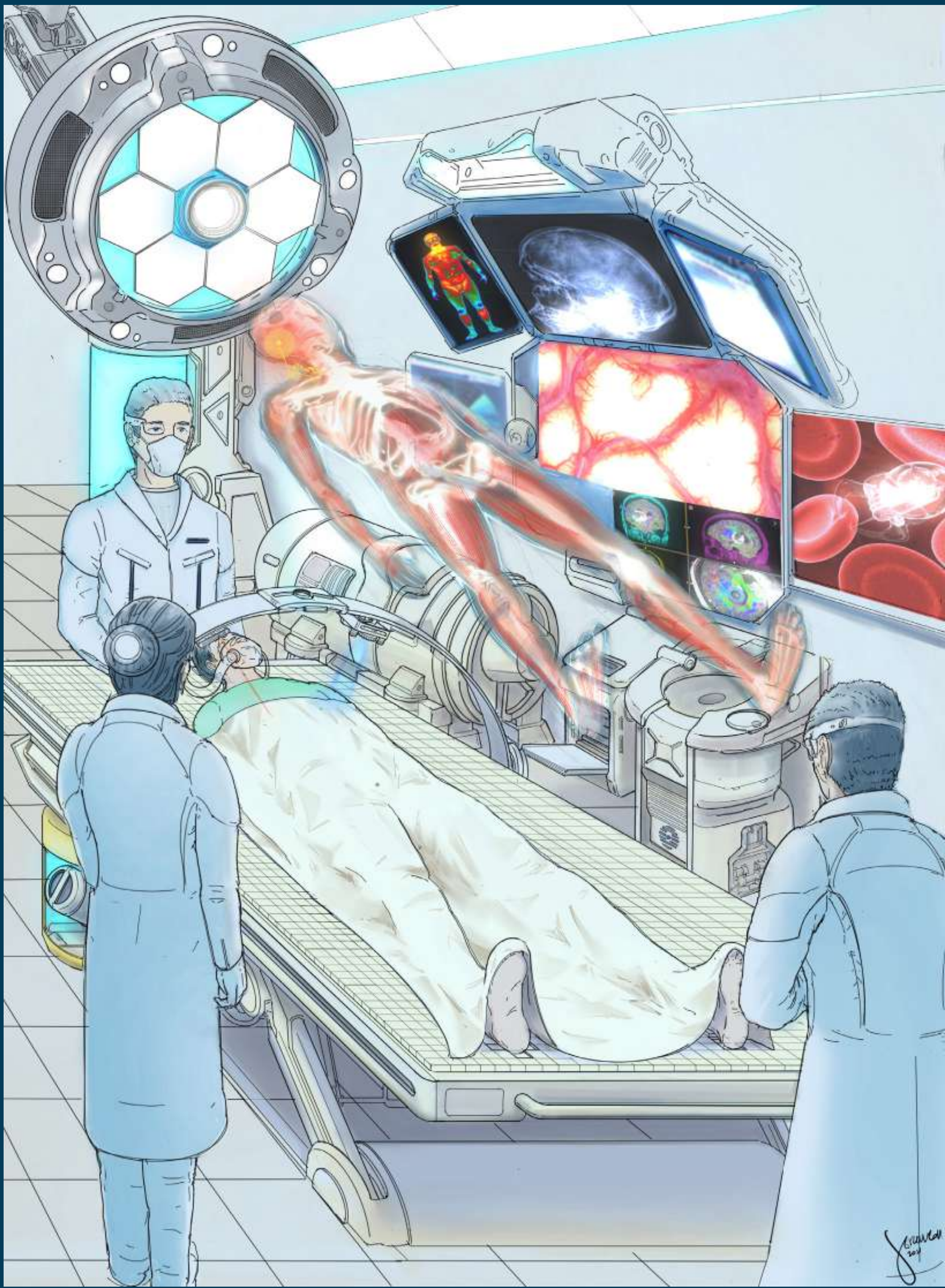
Advances in data processing will continue while putting emphasis on the creation of climate data records, where data quality conforms to the strictest standards. It is imperative that by this time, a robust ground calibration network such as spectrometers, Light Detection and Ranging, and flux towers are established around the country. The Philippines should also embark on continuity earth observation (EO) missions (e.g., Landsat program) to ensure the collection of physical, chemical, and biological variables that are essential in understanding the Earth's climate. Assimilating these observations in models will give the Philippines more accurate weather forecasts and reliable climate projections for planning and policy recommendations.

Furthermore, we should also consider participating in international EO missions, which will be more cost-effective and could address more comprehensive science questions like the constellation of hyperspectral satellites that can monitor essential biodiversity variables of coastal ecosystems (Muller-Karger et al. 2018). Other applications of spaceborne data such as in space weather, telecommunication, and navigation should also be maximized. In the long term, the desired outcome for mobilizing satellite images and spaceborne data downstream is achieved when decision support systems and evidence-based policies are cascaded into society.

Summary and Conclusion

The critical need to be involved in space technology has led to the creation of the Philippine Space Agency in 2019. Starting with a very modest budget allocation, the short-term goals and long-term goals are discussed in terms of upstream and downstream needs eventually leading to a fully functional and impactful space agency. The strategy for the upstream is to develop expertise in space technology through capacity-building and know-how transfer through international cooperation. Current plans to launch new satellite systems will continue with the help of other countries and at the same time develop and enhance local capabilities in space technology. In the longer term, the agency plans to develop the capability to build rockets and become less dependent on other countries in the launch of satellite systems. This will enable the timely launch of satellites we need for environmental, risk assessment, climate studies, communication, and navigation. On the downstream, currently available data from various sources, including freely available data from other countries, will be processed, converted to geophysical parameters of the archipelago and its maritime territory and distributed to agencies and legislators that need them for policy making decisions and scientists from universities and other institutions that need them to conduct research. Expert systems will be developed using artificial intelligence to better fulfill the basic missions in food security, safe domestic water and risk management.

By engaging in both the upstream and downstream of space, we can instantiate a virtuous cycle that we should nurture and feed. The virtuous cycle will enable us to develop and sustain endogenous science and technology capacity that can supplant the vicious cycle of technological dependence.



DIGITAL ARTWORK

Medical Technology

Primary conceptual idea by Timothy James Dimacali, Julius Sempio, and Jerome Suplemento II
Art by Jerome Suplemento II

The future of medical technology lies in the ability to safely plumb the depths of the human body to root out sickness and disease while maintaining the Hippocratic oath to "do no harm." Here we see the potential development of various scanning and display technologies that will enable a comprehensive visualization and understanding of a patient' s body, enabling medical personnel to quickly assess a proper diagnosis and decide on the best course of medical action with minimal or no need for invasive testing procedures.

SECTION 5

Uncertainties, Risks, Shocks, and Black Swans

The operational areas identified in this Foresight are intended to enable the realization of the aspirations of the Filipino people towards a state of wellbeing. Various approaches and particular technologies have been identified for this 30-year journey towards inclusive and equitable development. This section identifies the uncertainties, risks, and shocks that may arise during the implementation of the science, technology, and innovation (STI) inputs for the national development agenda, intended to benefit 144 million Filipinos by the year 2050.

Will growth and scarcity generate their own technological and social solutions?

There is disagreement on the nature of the problem (Warner et al. 1996). There are those who feel that the limits imposed by scarce resources can be resolved technologically and socially even as the human population continues to put pressure to satisfy its needs. Others propose to impose radical measures for population control. While a third approach is to balance "continued growth with the preservation of the world ecosystem" (Warner et al. 1996; Vitousek et al. 1997).

The COVID-19 pandemic has exposed in a more pronounced manner the fragile situation of the global and local economies and the inequalities that have been created in the long history of development (World Bank 2017; UNIDO 2018; FAO 2020b; UNCBD Secretariat 2020).

The technosphere, also mentioned in earlier sections of this Foresight, is a "network whose nodes, or intersection points, are people and technological artifacts. Energy, materials, information, and other essentials flow through the links that connect these nodes" (Haff 2013, 2017). Its components are "the world's humans, its transportation, communication, information, power, financial, education, and health systems and the world's cities, farms, militaries, bureaucracies, and other social-technological organizations, all technological systems and artifacts requiring energy and materials for their function or maintenance, as well as humans, are components of the technosphere." Haff (2017) considers the technosphere as the defining system of the Anthropocene, the unofficial name of the current historical epoch.

The technosphere has brought about new forces and conditions that have radically changed our environment and is now tasked with the challenge of recycling its products, by-products, and waste materials—including its huge mountain of products that have become obsolete (Haff 2013).

This section will deal with the functionality of the STI system—i.e., its ability to withstand, survive, sustain its activities in the face of uncertainties, risks, and shocks—when events that are not supposed to happen take place. Since human beings are vital to the survival of the technosphere, managing the interaction between human beings and technology, including their attendant material and energy flows, is the key to the functionality of the technosphere (Haff 2014). Human beings provide the brain power, the imagination, and creativity to keep the system going in the face of uncertainties and risks.

The Uncertainties, Risks, and Shocks

Recent progress in science and technology has enabled us to see more, detect more, sense more, and know more—moreso at our moments of dire need. Nevertheless, as we pursue new knowledge and innovation, there are uncertainties, risks, and shocks that have to be dealt with. Rapid and complex developments in the social, economic, environmental, political, and technological scene at the global and national domain are accompanied by varying levels of uncertainties, risks, and shocks, also known as "black swans," that have an impact on our ability to create wealth and promote national well-being (Magruk 2017).

Using available information and tools to gather data allows us to gain an idea of the nature of the uncertainty, risks, and shocks that may be encountered during the development of STI. Predicting the consequences of such vulnerabilities is a big challenge and at times may not be possible at all. Nevertheless, the intent of foresight is to identify the possible uncertainties, risks, and shocks and determine their possible positive or negative impact, time of occurrence and extent of disruption or impact.

The "black swan" is a highly improbable and shocking occurrence and is characterized by three attributes (Taleb 2010):

- It is an outlier: "lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility." (Taleb 2010)
- Extreme impact
- Can only be explained after the occurrence

An example of a black swan occurrence is the 9/11 attack on the World Trade Center in New York City. It is an uncommon event that resulted in the loss of many lives, destruction of property, and the tightening of travel security. Only after the event was an explanation of the circumstances that led to such an incident made possible.

The rapid pace and increasing complexity of developments, globally and locally, exacerbate the occurrence of black swan, as well as uncertainties and risks. Aven (2015) proposed a classification of black swan events as follows:

- Unknown unknowns such as 9/11 attack on the World Trade Center
- Unknown knowns (knowledge of the possible risk is known by others) such as the crew of a fishing boat deciding to face the storm, ending in tragedy.
- Events with negligible probability of occurrence such as accidents in an oil and gas installation.

A more rigorous level of analysis of these vulnerabilities will be important inputs in the creation and assessment of scenarios that will be the basis for strategies in the conduct of specific STI activities. For purposes of this Foresight, it might suffice to list the possible uncertainties and risks that might be perceived in the light of current circumstances; black swans, by definition, are all but impossible to identify.

In a report for McKinsey and Company, Baumgartner et al. (2020) identified vulnerabilities in the industrial supply chains that can affect efficiency, and provided estimates on their magnitude of disruption, frequency, and ability to be anticipated. These uncertainties have been identified in the context of industrial supply chains but can nevertheless affect any—and possibly even all—the operational areas in this Foresight. The following are sample disruptions classified by the estimated lead time in which they can be anticipated:

- Days
    - Acute climate events (hurricanes, typhoons)
    - Idiosyncratic event (dirty bomb)
- Weeks
    - Extreme pandemic
    - Financial crisis
    - Regulation and changes thereof
    - Super volcano eruption
    - Pandemic
    - Acute climate event (heat wave)
- Months
    - Global military conflict
    - Trade disputes, collapse of regional coalitions and withdrawal from trade agreements
    - Local military conflict
- Difficult to anticipate
    - Meteoroid strikes

- Solar storms
- Extreme terrorism
- Systemic cyberattack
- Major geophysical event
- Terrorism
- Human-made disaster
- Common cyberattack
- Counterfeit
- Theft

In addition to the abovementioned vulnerabilities, the global trends identified in previous sections of this report will also affect the Philippines' STI activities. Viewed in a larger context, the above vulnerabilities will also disrupt the functions of the knowledge infrastructure, the flow of knowledge, and the mobility of STI human resources. In addition to the disruptions identified in the McKinsey Report (Baumgartener et al. 2020), there are also other issues that can stop, interrupt, suspend, hamper, delay and retard STI activities, especially the deployment of technologies in the operational areas of this Foresight. Some of these vulnerabilities may be similar to those in the McKinsey Report, albeit occuring locally. This list is by no means complete, but we offer the following areas as possible sources of uncertainties, interruptions, and delay in the STI sector:

- Natural disasters in areas where field experiments are being conducted: typhoons, volcanic eruptions, earthquakes, droughts, floods, pests, diseases
  - Data collection and the destruction of the scientific equipment, e.g., Doppler Tower recently destroyed by Typhoon Rolly in Catanduanes
- Stresses, possibly brought about by climate change, that will affect experiments in crops, livestock and poultry, and fisheries
  - Abiotic stresses like drought, soil nutrient deficiencies, pollution
  - Pests and diseases of humans, animal, and plants including zoonotic disease
- Disruptions in the STI Knowledge Infrastructure (K-12 schools, public and private HEIs, Voc-Tech training centers, research institutions)
  - Quality of training in the STI knowledge infrastructure
  - Disruptions in the information infrastructure especially in telecommunications
  - Demand for talent to address development problems such as environmental pollution, technical assistance to MSME and access to cost-effective technologies to address minimum basic needs
  - Migration of STI talent through the OFW program of the Philippine government
  - Competition for highly trained STI talent from other countries
  - Protectionism by countries resulting in the restriction of access to new knowledge

  - Cost-effective online courses from more advanced countries might render some the curricular offerings in Philippine HEIs redundant.
- Major changes in the development agenda and support for STI brought about by change in government leadership
  - On the positive side, a significant increase in STI investment from the public and private sector may challenge the absorptive capacity of the research and development community
  - Resistance to technological change (Mokyr 1992)
- Management of STI Activities
  - Increase of inequality
  - Unintended consequences of technologies such as displacement of labor, generation of toxic wastes, etc. (Acemoglu and Restrepo 2019)
  - Disruption in the supply chain of research equipment and materials
  - Funding of STI activities
- Flow of R&D funds is hampered by absorptive capacity
  - Regulatory regimes affecting the timely procurement and supply of research materials and equipment
  - Indicators for assessing scientific activity and compliance with global initiatives such as the SDG, the evaluation of scholarly publications and the target density of R&D workers per million population. (Acemoglu et al. 2014)
  - Research Management and Grants Administration Systems in public and private institutions engaged in R&D
  - Reliable and updated database on public and private investments in R&D
  - Market-driven R&D agenda
  - Reorganization of DOST
  - Coordination among DOST, DA, DENR, DOH, DICT, CHED, TESDA, SUCs, Professional Regulation Commission, Private Sector R&D, National Innovation Council
  - Implementation laws affecting STI
  - Communication program to improve public understanding of science and to promote a culture for innovation
- Competition from other countries, especially ASEAN, that will render some of our R&D work redundant.
- Recovery from the negative impact of the COVID-19 pandemic

Anti-Science Movements

Past events such as the Luddites, the Scopes trial, the Nazi efforts on eugenics, attacks on genetics, space science, and the vaccines have fueled the intensification of the current antiscience movement which is increasingly becoming global. These assaults have been picked up by some politicians to further their political careers. When decisions of great impact are made based on biased information, the long-term, sometime irreversible effects can be disastrous. For a country like the Philippines that has to catch-up in science, technology, and innovation, the antiscience movement can have a crippling effect and will further delay efforts to address uniquely local problems (Hotez 2021).

Conclusion

Resilience and agility in the governance of STI will allow us to cope with uncertainties, risks, and shocks, whether they occur as isolated events or in combination. Holling (1973) defines resilience as the ability of an ecosystem to "absorb changes and still exist." Agility is defined as the "ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety" (Christopher et al. 2000). It is noted that resilience and agility may overlap in certain situations.

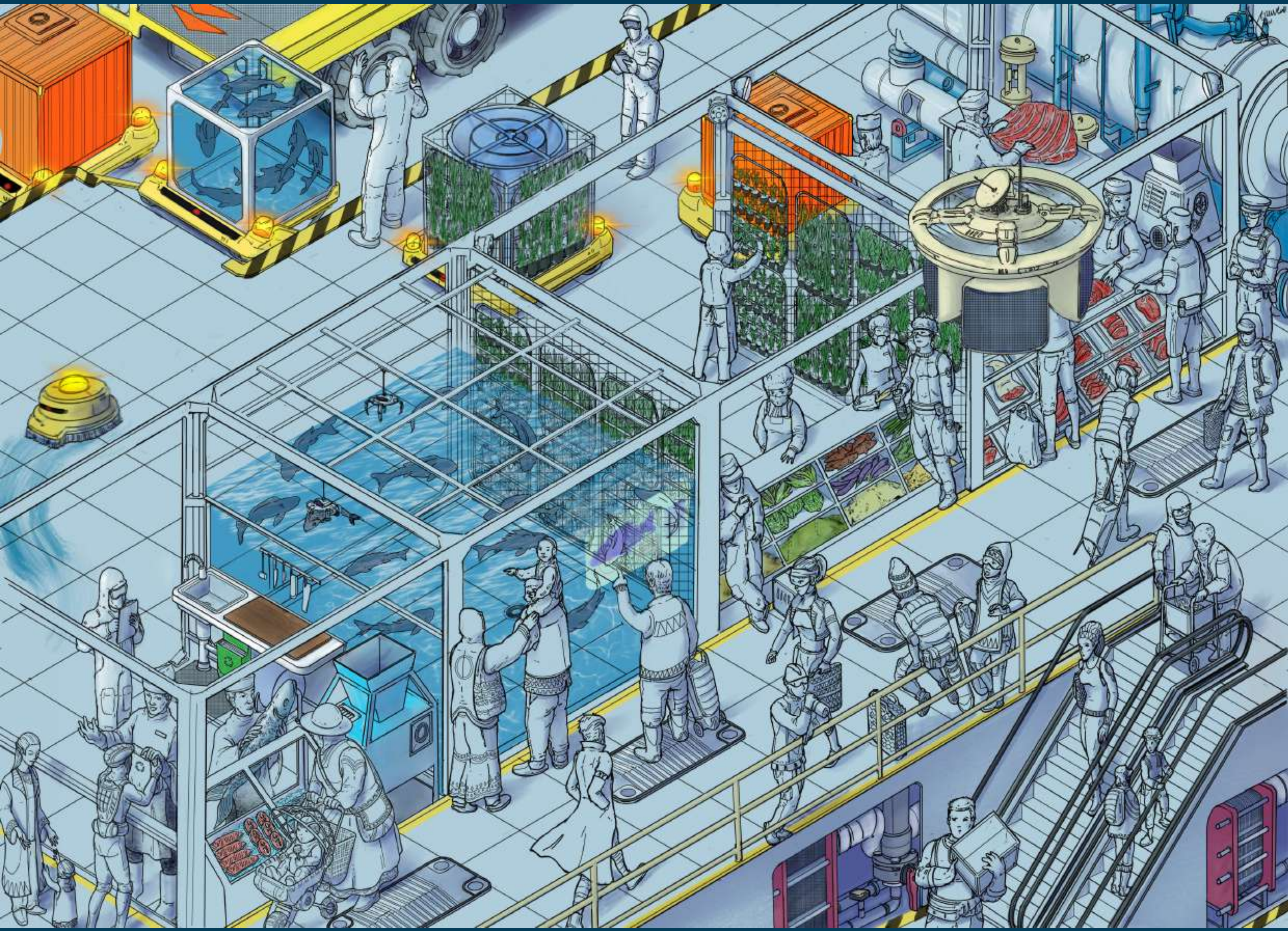
There are four concerns that need to be seriously considered in the management of response to uncertainties, risks and shocks:

First, coping with these vulnerabilities should not create nor exacerbate inequalities. Inequality is a barrier to the realization of the full potential of human beings (Cozzens 2008, 2016) and STI must not be used to create these inequalities. The COVID-19 pandemic has intensified the existence of these inequalities which can no longer be ignored such as access to health care, livelihood, and continuous learning.

Second, our enthusiasm to generate new technologies has messed up our environment. We will now have to correct the negative effects of the technosphere that we created especially in the recycling and disposal of waste materials and products that have outlived their usefulness. This seeming neglect has inflicted damage to our environment and affected the quality of life. This is best exemplified by the solid wastes generated by wanton use of plastics of various types.

Third, we should not lose control of the technosphere, which is gradually acquiring a life of its own (Ialenti 2020). Booby traps are already emerging such as the overshadowing of refereed journal articles by blogs, the threat of displacement of labor by automation, and, as cited by Johnson et al. (2012), the possible abuses that could result from the application of artificial intelligence.

Lastly, the antiscience movement will certainly affect the application of the rigor of science to support human flourishing and not the collapse of societies. It is our duty to build the intellectual infrastructure that will live beyond anyproduct of the technosphere.



DIGITAL ARTWORK

Marketplace

Primary conceptual idea by Jerome Suplemento II, Timothy James Dimacali, and Julius Sempio
Art by Jerome Suplemento II

The Talipapa, or small wet market, is a central feature of Philippine society—an accessible and convenient place to buy affordable foodstuffs and other essentials. In the future, small and medium enterprises will be able to do business with their customers in a clean, sanitized, and well-maintained public space. Robot cleaners and sensor-equipped sanitation personnel and product inspectors will help maintain a consistently sanitary environment amid the usual bustle of the marketplace.

SECTION 6

A Roadmap to the Future

SECTION 6.1
DELPHI SURVEYS, TECHNOLOGY CLUSTERS, AND FORESIGHTING

DELPHI Survey Results

After two rounds of Delphi surveys (see Section 1.1), respondents from across the National Academy of Science and Technology, Philippines (NAST PHL) and experts managed to reach a consensus on the ten key points (Table 6.1_1).

Seventy-four percent of 206 respondents expected changes in the aspirations outlined in AmBisyon Natin 2040 due to COVID-19. Based on rankings, respondents named the following as the topmost priorities:

(1) eliminate poverty and hunger
(2) ensure improved wellbeing of Filipinos (well-being here is the state of being happy, comfortable, and healthy)
(3) foster innovation

The above-mentioned priorities were also reflected in the top trends that respondents considered in the foresight. Expectedly, the topmost answer was growing poverty and hunger. These were followed by climate change and deepening environment risks and growing inequality. Respondents also agreed that the most significant disruption as Filipinos journey to 2050 would be the recovery from globally disruptive events such as pandemics and armed conflicts. Acute climate events came in second, followed by the sustainability of science, technology, and innovation (STI) interventions.

In terms of adequacy of the current STI foresight, 69% of 243 respondents did not name additional areas for consideration. Marine science was identified as the field of current strength of STI in the Philippines. Excellence was also observed in agriculture with rice science and technology and major export crops. Respondents also evaluated the importance and feasibility of the Philippines as the leading global or regional centers in the following areas by 2050:

(1) regional center of agricultural biotechnology research, development, and innovation
(2) leading global center of excellence in marine science
(3) leading global center in disaster risk management

When asked about public and private institutional and organizational changes needed to enhance the role of STI in the development and daily lives of Filipinos, there was consensus that changes are needed to improve the quality of Science, Technology, Engineering, and Mathematics (STEM) instruction in K-12. This was followed by the improvement in the quality of instruction at the undergraduate level in Philippine Higher Education Institutions (HEIs) while science literacy program development and institutionalization were third. Aside from changes in public and private organizations and institutions, respondents answered questions on the improvement of quality and quantity of talent development and retention in STI. The following mechanisms were ranked based on importance:

(1) create attractive, regular, and stable employment opportunities for highly trained STI workers in the public and private sector
(2) improve the ecosystem for the conduct of research and development (R&D) in the Philippines
(3) expand incentives for the Philippines to be attractive to knowledge workers (local and foreign) including formulation of appropriate immigration policies and review of relevant existing laws

The respondents also believed that STI could be harnessed to assert our sovereignty and identity as a maritime nation. Almost 70% of 243 respondents said all of the following should be done concerning the Philippine seas:

- publish and popularize and widely disseminate a scientifically designed map showing the maritime territorial limits of the Philippines as confirmed by international bodies like UNCLOS and the Tribunal
- expand surveillance capability of the Philippine Coast Guard to effectively monitor our territorial limits by using well-designed watercrafts and sensors attached to autonomous unmanned water vehicles
- initiate wider exploration of the Philippine territorial waters for valuable and strategic natural resources
- support R&D initiatives to work on an inventory of biological resources in Philippine territorial waters
- collaborate with other countries in Asia for an integrated marine resource management program

The last part of the Delphi survey dealt with public investments and interventions and STIs that could stimulate and shape technologies to reduce poverty or conditions associated with poverty. Respondents had a consensus that public investments should be allotted to ensuring equitable access to nutritious and affordable food. This was followed by the following: improving access to clean domestic water supply and sanitation in rural areas and urban slums and designing and implementing resilient and efficient supply chains.

Table 6.1_1. Top Three Answers in the Delphi Survey Questions

Delphi Survey Questions	Top Three Answers
1. Do you expect any changes in the expressed aspirations in the light of the COVID-19 pandemic (including the post-pandemic period 10 years hence) until the mid-century year 2050?	(1) eliminate poverty and hunger (2) ensure improved wellbeing of Filipinos (wellbeing here is the state of being happy, comfortable, and healthy) (3) foster innovation
2. What socio-cultural, technological, economic, environmental, and political megatrends, both global and local, should be considered in this foresight exercise?	(1) growing poverty and hunger (2) climate change and deepening environment risks (3) growing inequality
3. What uncertainties, black swans or disruptions do you expect as we journey 2050?	(1) recovery from globally disruptive events such as pandemics and armed conflicts (2) acute climate event came in second (3) sustainability of STI interventions.
4. Are there additional areas that we need to consider for this STI Foresight?	No additional areas for consideration.
5. What do you perceive as the current areas of excellence/strength in STI (including the social sciences) in the Philippines?	(1) marine science (2) rice science and technology (3) major export crops
6. What additional areas of excellence/strength would you want the Philippine STI (including the social sciences) to be leading global or regional centers by 2050?	(1) regional center of agricultural biotechnology research, development, and innovation (2) leading global center of excellence in marine science (3) leading global center in disaster risk management
7. What public and private institutional or organizational changes should take place to enhance the role of STI in development and in the daily lives of the Filipinos? (e.g., Public-Private Partnership in R&D, reorganization of DOST, STEM instruction in K-12, etc.)	(1) improve the quality of STEM instruction in K-12 (2) improve the quality of instruction at the undergraduate level in Philippine HEIs (3) science literacy program development and institutionalization
8. What measures should be taken to improve the quality and quantity of talent development and retention in STI?	(1) create attractive, regular, and stable employment opportunities for highly trained STI workers in the public and private sector (2) improve the ecosystem for the conduct of R&D in the Philippines (3) expand incentives for the Philippines to be attractive to knowledge workers (local and foreign) including formulation of appropriate immigration policies and review of relevant existing laws.
9. How can STI be harnessed to assert our sovereignty and identity as a maritime nation?	All of the following should be done concerning the Philippine seas: publish, popularize and widely disseminate a scientifically designed map showing the maritime territorial limits of the Philippines; expand surveillance capability of the Philippine Coast Guard; initiate wider exploration of the Philippine territorial waters; support R&D; and collaborate with other countries in Asia.
10. What public investments and interventions in STI can stimulate and shape technology to reduce poverty or the conditions associated with poverty by providing opportunities for those who are living at the edge of subsistence?	(1) ensure equitable access to nutritious and affordable food (2) improve access to clean domestic water supply and sanitation in rural areas and urban slums (3) design and implement resilient and efficient supply chains

SECTION 6.2
THE SCIENCE, TECHNOLOGY, AND INNOVATION ROADMAP

This Science, Technology, and Innovation (STI) Foresight culminates with the STI Roadmap that reiterates cluster goals for the preferred future, science, and technology (S&T) enablers, drivers, and opportunities. The roadmap is a product of numerous National Academy of Science and Technology activities, including technology forecasting (Salvacion 2020), Delphi survey, virtual workshop on the scenario planning, focus group discussions, technology mapping, and iterations with the NAST Foresight Steering Committee.

The framework of the Integrated STI Roadmap consists of four parts (Figure 6.2_1) namely:

- Four innovation phases
- STI Clusters
- Science and technology enablers
- Drivers and opportunities

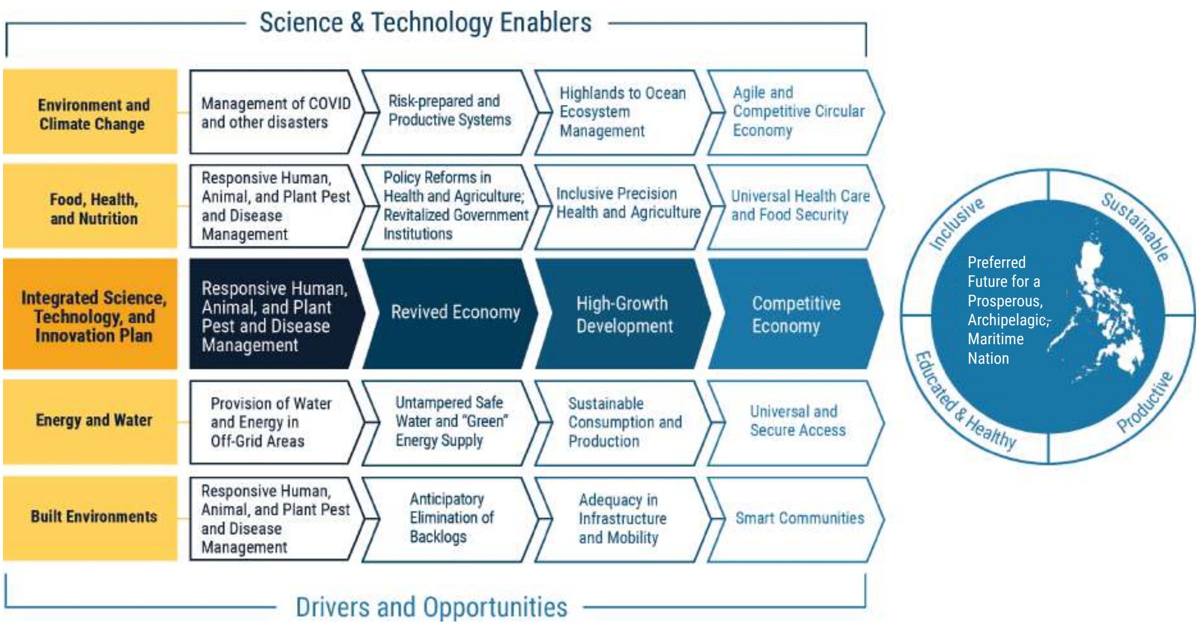


Figure 6.2_1. Integrated STI Roadmap

Innovation Phases

The four innovation phases start with the recovery period through the Responsible Management of Pests and Diseases. As of this writing, the COVID-19 pandemic continues to infect thousands and the African Swine Flu has also infected significant numbers of the swine industry. Thus, the need to harness the know-how from STI to contain the spread of variants of COVID-19 and other diseases that affect not only humans but also the sources of food such as crops, livestock, poultry, and fisheries.

The recovery phase is then followed by the Revival of the Economy where the inertia imposed by the pandemic is replaced by the momentum of activities that will set the stage for the next innovation phase for High Growth Development.

The third phase is characterized by the application of advanced technologies to enhance economic growth and national well-being.

The fourth innovation phase is characterized as a Competitive Economy marked by the entry of a good number of Philippine products and services in the global market.

Due to uncertainties, risks, and shocks, including the black swans, that may occur within the 30-year period of this foresight, no fixed timelines have been indicated for the four innovation phases. The pace of development may differ among the four clusters.

The goal of the STI Roadmap is for the Philippines to eventually become a Prosperous, Archipelagic, Maritime Nation characterized by a society that is inclusive, productive, sustainable, educated, and healthy.

Science, Technology, and Innovation Clusters

As indicated in the earlier parts of this Foresight, the six of the operational areas have been grouped into four clusters based on their close relationships in STI. The four clusters are:

- Environment and Climate Change
- Food, Nutrition, and Health
- Energy and Water
- Built Environments (Shelter, Transportation, and Other Infrastructure)

The integrated futures within and across clusters were derived mainly from the back casting discussions.

Science and Technology Enablers

The S&T enablers include existing technologies and areas that serve as backbones of successful STIs, such as science education, business and trade, blue economy, and governance. These technologies and operational areas provide the tools, and the know-how that will enable the socio-cultural, technological, economic,environmental, and political factors to work harmoniously towards national well-being.

Drivers and Opportunities

Uncertainties, risks, and shocks brought about by natural disasters and human events are both drivers and opportunities for change. The pace of the developments in each innovation phase will be determined by how well Philippine society and its leaders have been able to discern, anticipate, and manage disruption and/or the opportunities brought about by the social, technological, economic, environmental, and political forces that emerge during the period of this Foresight.

Environment, Climate Change, and Space Exploration Cluster

While commonalities could be observed in the maps, goals are unique, and some S&T enablers, drivers, and opportunities are inherent in a particular cluster.

For the Environment and Climate Change cluster (Figure 6.2_2), the initial goal for the recovery period is to effectively manage COVID-19 and other pests and diseases including those that affect food crops, livestock, poultry, and fisheries. This is necessary for the cluster to achieve an agile and competitive circular economy. It is anticipated that the act of balancing between development and protection of the environment/resources will become more challenging as more people compete for survival, livelihood, and economic gains.

Drivers for this cluster include natural disasters like floods, landslides, and tsunamis from seismic events or typhoons with heavy precipitation and strong winds. Other land- and marine-based disasters such as outbreak of diseases in humans, plants, and animals that may be influenced by climate change related phenomena like prolonged El Niño and La Niña, rise in land and sea surface temperature, sea level rise, and ocean acidification. Land and marine pollution are generally anthropogenic and inter-related whose negative impacts are exacerbated by climate change.

At the local or national level, opportunities include industrialization with accompanying infrastructure and technological development and utilization in the areas of agriculture, aquaculture, and fisheries. Long term terrestrial and marine space mapping and promotion should be embedded with coordinated hazard and risk management of an STI enabled integrated ecosystems framework. The establishment of the Philippine Space Agency (PhilSA), is a significant STI enabler and influencer on both the protection of the environment and biodiversity resources and utilization for competitiveness.

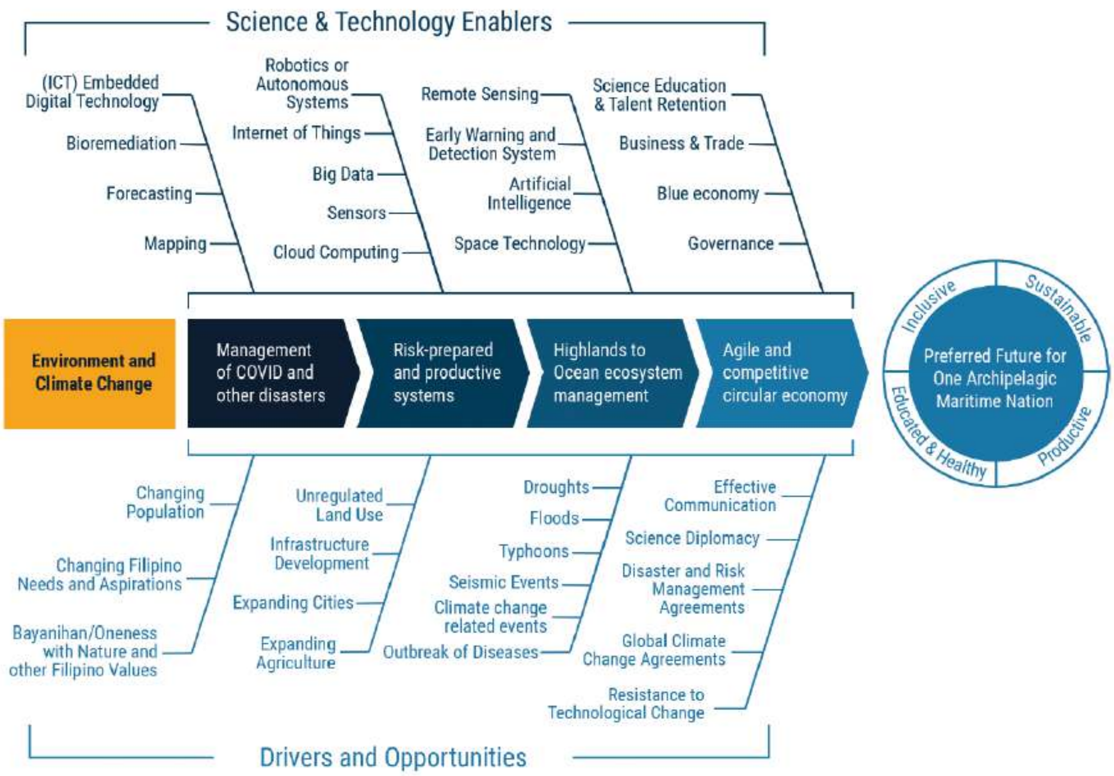


Figure 6.2_2. Environment, Climate Change, and Space Exploration Cluster Map

Philippine demography and population health and well-being will weigh heavily on the progress of this cluster. Poverty incidence, if not curbed or stopped significantly can continuously negatively impact the environment/ resources particularly, in the area of pollution. Filipino values like the bayanihan spirit nationalism/love of country of our forefathers and our indigenous tribes "oneness with nature" should be harnessed formally and informally especially among the youth. Effective science communication must be pursued.

At the regional and global level, climate change issues and management will continue to be a major influencer on the environment and biodiversity. Regional and global agreements and guidelines on manufacturing, business and trade, among others, will be guided by climate change management and carbon footprints and credits. The Philippines should be able to participate well and effectively in the consultation and discussions of these S&T issues at the regional and global arena using "science diplomacy" and "diplomacy for science" with the present interests and future of the nation as priority.

S&T enablers in this cluster are related to the other clusters but with focus on specific needs and advancements in the areas of environment, climate change, and space exploration. Biotechnology and nanotechnology are useful for innovations on multi-sensor and robotics/autonomous systems development. Information and communications technology will empower all aspects of operations in the cluster together with big data analytics and artificial intelligence. Terrestrial and marine integrated spatial planning and ecosystems management should be embedded with disaster management and technologies for early warning and mitigation. Applications (Apps) for technical and other stakeholders' use in disaster prevention and mitigation should be further enhanced. The Department of Science and Technology's GeoRisk Philippines that identifies landslide prone areas should be expanded to include other hazards and risks. The PhilSA should be strengthened with financial, infrastructure, and manpower support to enable the agency to perform its various roles in the protection and utilization of the environment and resources and climate change related problems of the country, navigation, and national security.

The overarching enablers for this and the other clusters should be the results of interlinked STI. Science education and talent retention to power up this cluster is in its infancy stage, including informal education. Governance of the environment and climate change impacts and use of space technology/apps from the local/lowest level to the national level should be embedded in a vision of a "reinvented STI ecosystem" where currently, decision making is fragmented. The Business and Trade sector should be STI-equipped to meet local and global needs and opportunities in this cluster, and its plan of actions should include short and long term effects to the environment and climate change impacts.

A game changing enabler is the blue economy platform. It espouses the inclusive growth of the population through the sustainable use of living and non-living resources and protection of coastal and marine environments. A circular economy with production-consumption rate balanced estimate is vital in a competitive, inclusive, and sustainable maritime nation.

The cluster road map does not show years to delineate the different stages towards the end of the road or goal. This is to encourage the hastened but careful and coordinated analysis, planning and implementation of actions to reach every stage in the least possible time while considering the interactions and interrelationships with the other operational areas/clusters. The first stage in the map is called the "COVID pandemic, and other risks responsively managed", an ongoing period where effective "survival" adaptations in this highly disruptive stage are critical to enable us to proceed to the next stage . The second stage is called "circular economy with anticipatory disaster risk management" The third stage should also overlap or integrate early with the previous stage and this is called " agile and competitive circular economy."

Food, Nutrition, and Health Cluster

For the Food, Nutrition, and Health Cluster (Figure 6.2_3), the initial goal is similar to the Environment, Climate Change, and Space Exploration and the Built Environments clusters. This is followed by policy reforms in health and agriculture, revitalized government institutions, inclusive precision health and agriculture, and universal health care and food security.

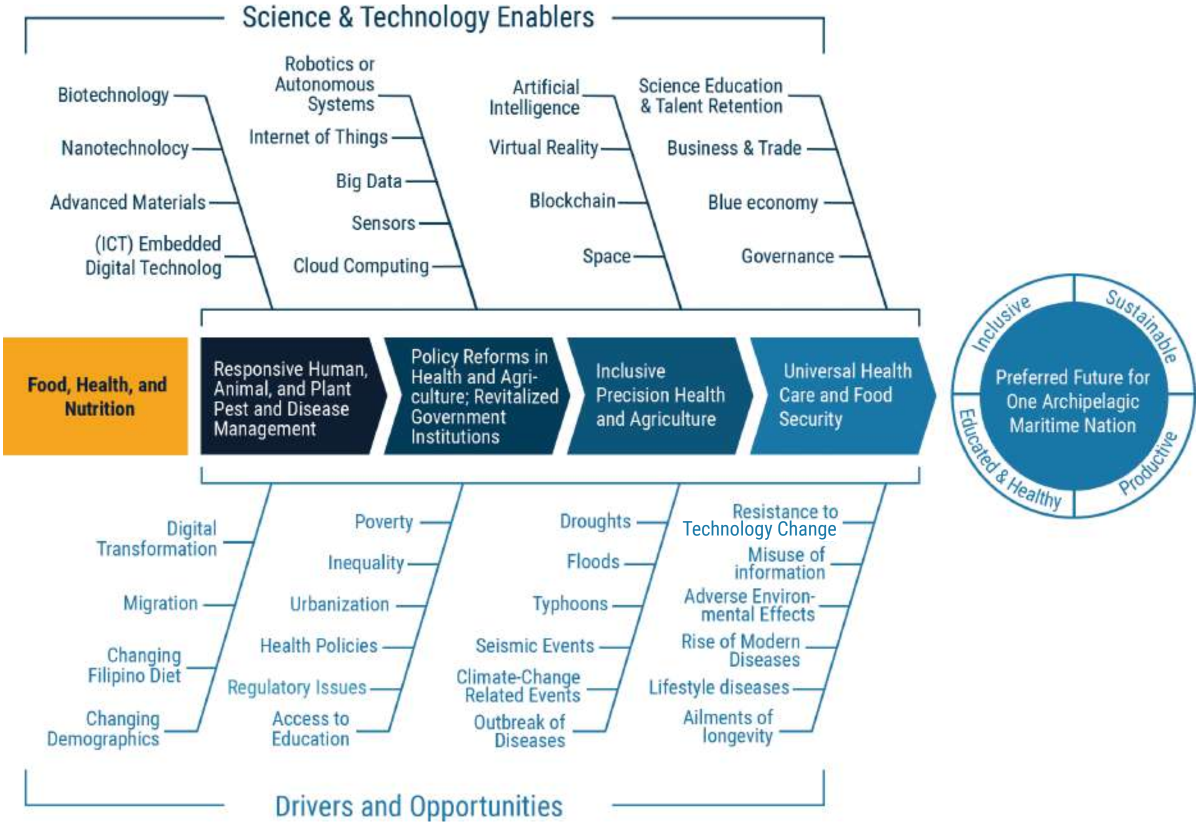


Figure 6.2_3. Food, Nutrition, and Health Cluster Map

The indicators used to measure poverty are based on counting the "individuals and families whose income fall below the poverty threshold as defined by NEDA and/or cannot afford in a sustained manner to provide their minimum basic needs of food, health, education, housing, and other essential amenities of life" all of which are embodied in RA 8425 (Mapa 2020). Thus, concerns about food, nutrition, and health are paramount in the quest towards poverty elimination.

The scenario for Food, Nutrition, and Health from 2021 to 2050 spans a period of close to 30 years towards a food secure nation that enjoys full benefits of universal health care both of which are critical to attain the goal of being a prosperous, archipelagic, maritime nation and being the healthiest nation in the world.

The role of agriculture in improving the status of health and nutrition of our country has not been fully realized. According to Fan (2011) agricultural growth should consider its impact on health and nutrition by devising strategies that will "minimize risks and maximize the benefits to nutrition and health across the entire value chain, from production to consumption."

This scenario starts in the COVID-19 pandemic setting that has caused widespread suffering across sectors and countries including the economic downturn that has increased those experiencing hunger and poverty. Thus, the challenge is for science, technology, and innovation to provide the tools to responsibly manage the incidence of pests and diseases in humans and in animals and plants with high economic value and at the same time, set the stage for the revival of the economy, followed by improvement in productivity to create new wealth in a sustainable manner.

Living systems are the pillars of agriculture and health. The state of the living systems is in turn affected by the materials obtained by the organism to provide the structure and energy to sustain the processes to keep the living systems functioning within the influence of the environment. In addition to the traditional disciplines of systematics, physiology, anatomy, morphology, microbiology, virology, evolution, among others, S&T have progressed in the last two decades to provide the basic tools to better understand life's processes such as:

- Genomics
- Structural Genomics
- Functional Genomics
- Transcriptomics
- Proteomics
- Metabolomics
- Structural Biology
- Synthetic Biology
- Pharmacogenomics
- Pharmacogenetics
- Nutraceuticals
- Nutrigenomics
- Nutrigenetics
- High Speed, high-capacity chemometric methods
- High Speed, high-capacity computing
- Computational biology
- Quantum biology
- Quantitative biology
- Internet of Things (IoT)
- Sensors
- Big Data
- Artificial intelligence (AI)
- Nanotechnology and new materials
- Phenomics
- Autonomous Systems and Robotics
- Structure and Function of novel molecules
- Sociology
- Anthropology

Access and expertise in the above disciplines and their accompanying research techniques allow us to see more, detect more, and sense more in order to provide greater insights and in-depth approaches to innovate.

Innovation Stage I: Responsible Management of the COVID-19 Pandemic and other Pests and Diseases Affecting Human, Livestock and Poultry, and Food Crops

The starting point of this scenario is in the midst of the COVID-19 pandemic, accompanied by the infection of a significant part of the local swine industry by the African Swine Fever and isolated instances of Bird Flu, a poultry disease which can affect humans. The severity of the impact of the COVID-19 pandemic has disrupted the supply chain and dampened the demand in both the agriculture and health sectors.

Observers consider the COVID-19 pandemic mainly as a health problem and the challenge has been to balance the need to contain the spread and to continue whatever economic activity may be possible. The weaknesses of the health care delivery system in the public and private sector in the Philippine have been exposed and interventions had to be undertaken with urgency to reduce morbidity and mortality. The science community, especially in the health and life sciences, provided science-based advice as they were able, and the lack of expertise and facilities in human vaccine production was apparent. The establishment of the information infrastructure to monitor the spread of COVID-19 infection proceeded quite slowly and was often overtaken by events. During the recent outbreak, many COVID-19 patients found it difficult to gain admission to hospitals, and the health care workers found themselves overworked.

The challenge has been the need to balance the protection of the population's health and the economy. This is to be based on a robust surveillance system, as detailed as possible, by using digital technology (information and communication technology) to establish the information infrastructure that will monitor food safety and supply and the ability of our health care delivery system to respond to the pandemic.

Traditional food supply chains became vulnerable to supply fluctuations due to disruptions in storage, transportation and services. Similarly, the health care delivery system had to try its best to manage the situation in the light of the constraints.

Information about the extent of the infection, whether they be in humans, livestock and poultry and food crops, is crucial in designing interventions to prevent the further spread of the pest or pathogen. In addition to the surveillance system which consists of testing, contact tracing, and physical facilities for isolation and quarantine, the use of scientific tools to identify the pathogen or the pest, to treat infected persons, livestock and poultry and food crops, to determine the containment measures and the right treatment using social mechanisms, physical barriers, drugs, chemical compounds and devices. These present opportunities to develop the know-how and innovate in response to the needs of the times.

Research and development activities have not been exempt from the disruptions caused by COVID-19. Likewise, the educational system has been confronted with the possible loss of learning at all levels. Delays in R&D activities and localized infestation by pests and diseases in the agriculture and health sector has imposed additional constraints in attaining food security.

Innovation Stage II: Reviving the Economy: Policy Reforms in Health and Agriculture, Revitalized Institutions and Government Agencies

This innovation stage will revive and consolidate the gains achieved before the pandemic. Previous initiatives that have been disrupted in various ways will be reviewed and those that will lay the ground for a high-growth development will be set in motion.

The COVID-19 pandemic is believed to be an opportune tipping point to revive the economy towards our preferred future. The role of the agriculture and health sector will be vital to this effort because a workforce that has access to nutritious food and universal health care will be able to make the difference in reviving the economy using the tools of S&T. At this transition period, we expect to free ourselves from the constraints imposed by the pandemic and start mobilizing the population. This time, there will be new modes of social interaction among co-workers within an institution. Precautions will still have to be taken to prevent a resurgence of a pandemic or even an epidemic. The supply chain for goods and services will be revived to pre-pandemic capacity gradually.

The magnitude of the challenges that have to be managed can be gleaned from the population figures. As of the early part of April 2021, the World Population Review (2021) reports the Philippine population at 110,729,412 and projected to reach 144,488,158 by 2050, increasing at an annual rate of 1.39%, at one birth every 14 seconds. The population figures alone are daunting both in terms of coping with the food supply and the health care facilities. The increase in population will put pressure on our food supplies, educational facilities, and the health care delivery system to serve more than 7,000 islands and a vast maritime territory (World Population Review 2021).

Both our food system and health care system will have to be transformed after COVID-19. The features of an ideal food system are as follows (International Food Policy Research Institute 2021):

- Efficient – provide incentives and remove hurdles to deliver efficiencies in the supply chain
- Contribute to global health – provide affordable, nutritious foods, and guarding food safety
- Inclusive of small holder farmers and marginalized groups such as women, youth, the landless and refugees and displaced people
- Environmentally sustainable using technological innovations and governance approaches to conserve and protect natural resources and mitigate climate change

- Resilient – able to bounce back quickly from health, climate, and economic shocks, providing poor household with stable livelihoods that protect them from shocks

Reviving the economy is not just a mere reversion to pre-pandemic conditions. The revival stage must lay the ground for the transformation into a high growth development where opportunities to create new wealth will be open to all sectors of the population. This is the time to identify growth points by a careful and rigorous reading of both the domestic and global market for new and next generation products in food and health, especially those derived from marine sources. A sharpened focus on high value-added products in agriculture and the enhancement of health care services should now be initiated to set the stage for high growth development.

Furthermore, attention should be given to promote urban agriculture in the major urban centers in the Philippines such as Metro Manila, Metro Cebu, Davao City, Cagayan de Oro City, and Zamboanga City.

In addition to enhancing the nutritive content of food crops, the global market for plant-based ethnic food, flavors, spices, colorants, essences and drugs and other non-food products from plants and microbial sources must be explored and next generation products should be developed.

On the enhancement of health care delivery, the rational development must now be initiated to improve the carrying capacity of our health care system towards providing universal health care to an archipelagic and maritime nation. The activities should commence to further the application of technologies in IoT to monitor patients and status of health in communities, the use of big data and AI to analyze and gain insights on the efficiency and efficacy of measures leading to universal health care, the use of nanotechnology and new materials for medical products and devices, biotechnology to understand the nature of infectious and non-communicable disease, and the use of robotics as caregivers and delivery of treatment for infectious diseases. These are just a few examples of the vast opportunities to lay the ground for a high growth development agenda.

Innovation Stage III: High Growth Development: Inclusive Precision Health and Precision Agriculture

This stage shall involve a technology explicit agenda to develop a prosperous economy by creating new wealth with a highly skilled workforce, the outcomes of which are enjoyed all over the archipelago and fully cognizant of our maritime resource base. The following shall be the basis of the development agenda:

- Recruitment of talented, ingenious, and adaptive workforce – access to high-quality education in the Philippines and abroad; recruit talent from global market
- Economic efficiency-reliable supply of energy, efficient transport system, healthy workforce, provision of a reliable supply chain

especially for essential goods and services, all consistent with a circular economy
- Trade facilitation – major player in the global biocommerce market, functional national quality infrastructure, upgraded products in the services sector
- Food security – access to affordable, nutritious food, well-managed farms
- Environmental protection – establish the components of the circular economy through well-designed systems in the agriculture, industry and services sectors to minimize wastage and air, water, and land pollution, including functional recycling of wastes and obsolete materials
- Disaster risk management- all human settlements deployed in areas of low risk to natural disasters and
- Technology for national defense – increase investments in R&D of technologies related to national defense and national security. This includes the continuing issuance of the national identification card, surveillance of national territory against foreign aggression and illegal operations (logging, smuggling, etc.) and attract investments in a defense industry.

High growth development will depend on connecting and engaging the elements of the archipelago, the intensification of efforts to harness the maritime resources, and access to new knowledge through S&T. At this point, the population of the Philippines shall have increased to around 130 million and the Industrial Revolution 4.0 shall have transformed nations to deal with highly technological societies.

The Philippines shall now have sorted out the food-nutrition-health nexus and the nutritional status of the population shall have been improved considerably with stunting and malnutrition significantly diminished. The commitments of the Philippines in the targets set in the SDGs related to food and agriculture and the Climate Change Agreements shall have been accomplished.

At this point the manufacturing sector for high valued products, especially in the biocommerce market, shall be fully activated and fully coordinated with the raw material supply chain coming from agriculture and maritime resources. Likewise, the installation of clean energy sources shall be nearing full-national coverage and the cost of energy shall have gone down. Farms shall have been consolidated and operated profitably. The services sector such as tourism, health care, business process operations, and other new business prospects shall be efficiently operated.

Innovation Stage IV: Competitive Economy: Universal Health Care and Food Security

The capacity to extract, characterize, purify, and define the composition of raw materials and products in agriculture and health, especially from maritime and archipelagic sources, shall have been established within the

Philippines. This is expected to be the most significant contribution of S&T in gaining the advantage so vital is a competitive economy. The in-depth knowledge gained about these raw materials and products is the very foundation of a resilient and agile society allowing all sectors to plan on a roadmap to take remedial steps to get out of the rut or to minimize the effect of the disruptive forces that have inhibited or slowed down growth. Agility and resilience shall be the defining factor of a competitive economy in the midst of many risks and uncertainties and the frequent incidence of black swans or unexpected events. In other words, the reliability of the supply chain shall be a determining factor in sustaining business.

This stage shall see the manufacture of next generation products processed from marine sources: new, rapidly biodegradable materials, nutritious food, drugs, cosmetics, new biomaterials, etc. The intensified efforts in the search for unusual microorganisms shall bear fruit in terms of new biomaterials, new bioprocessing agents (heat-tolerant, minimal product feedback inhibition), new molecules, new reliable detection techniques for infectious microbial agents in human, livestock and poultry, and food crops. Furthermore, the features of an ideal food system shall have been substantially realized.

By 2050, governance shall be transformed to fit the mode of production of new wealth. The human resource and workforce will now be skilled to manage advanced technologies. Decisions shall be science-based taking into consideration the welfare of close to 150 million Filipinos whose nourishment and health must be assured. This will require massive resources that will be derived from new wealth, enhanced by the sustainable exploitation of maritime resources and the increased efficiency in the transformation of agricultural, maritime, and microbially-based products into profitable business ventures able to survive competition in the global biocommerce market and in the provision of health care services not only for the Filipinos but for patients coming from the region as well.

The Philippines will benefit from a healthcare ecosystem that maximizes value by empowering the patients, the providers, the social health insurance and the commercial insurance to achieve synergy through efficient governance and technology.

The proposed stages and timelines for tasks where STI will provide major inputs are in Figure 6.2_2.

A significant increase in the per capita GDP income shall have been achieved through an inclusive development strategy that considers our archipelagic and maritime resources as the platform. The survival, security and enabling needs of the Filipino people shall have been substantially provided and poverty levels shall be one of the lowest in the world.

Table 6.2_1. Proposed Phased Development of STI in Food, Nutrition, and Health

Themes	2021-2022	2022-2028	2028-2034	2034-2040	2040-2046
Policy	Review of existing policies, legislative action, and laws that negate health for all	Address issues resulting from increased number of working women Multisectoral institutionalization of the "health in all" policy approach.	Establishment of a model healthy community as proof-of-concept and basis for scaling up changes Model community linked with Bidani (Nutrition communities)	(none indicated)	Whole of nation approach to population management
Information Education Communication Campaign		Aggressive campaign against fast food eating habits Aggressive government intervention in shaping the diet of people and children (i.e., feeding program, disasters, etc.)	Promotion of healthy fast food through adoption of Japanese "Bento"		Education for children-should be digital in the form of games/Digital delivery of content/ message appropriate to the current audience facilitated by ICT and Artificial intelligence
Food production and delivery system	Intensify production of vegetables and fruits	Improvement of agricultural product delivery system Government to mediate a better distribution system through incentives Incentivize backyard farming and farming in general	Online fresh produce/ market (expansion and increased use) of e-Kadiwa Strengthen LGU's role in farm to market – provide seedlings for free; buyer of the produce (LGU will commit to buy produce; provide transportation to the market; identify the market Real farm to market distribution in place (removal of middleman; can be replaced by government)		Technology market for food, nutrition, and health – similar to electricity market, incentivized and made competitive to lower the costs
Healthy Lifestyle		Create an environment supportive to sustain healthy lifestyle Caloric labelling of fast food products as guide for healthier living Incentivize healthy food and impose sin tax on fast food Food menu reviewed	Personalized diet prescribed and connected to the food distribution systems		

Table 6.2_1. Continued

Themes	2021-2022	2022-2028	2028-2034	2034-2040	2040-2046
Technology		Innovation in infrastructure and physical sete-up for health and food systems	Online fresh produce/ market (expansion and increased use) of e-Kadiwa Personalized diet prescribed and connected to the food distribution systems Comprehensive health insurance system in place e-finance (financing technology in the health sector)		Education for children-should be digital in the form of games / Digital delivery of content/ message appropriate to the current audience facilitated by Information and Communications Technology (ICT) AI Technology market for food, nutrition and health – similar to electricity market, incentivized and made competitive to lower the costs.
					2046-2050 **Filipinos healthiest in the world**

Energy and Water Cluster

The recovery stage from the pandemic of the Energy and Water cluster aims for the provision of water and energy in off-grid areas. Risks from other natural and man-made disasters should be managed responsibly at this stage. By the second stage, unhampered supply of safe water and energy should be achieved. These resources should be calculated and maintained based on island or regional space planning and implementation. This is critical for transition to the next stage. The third stage, "Sustainable Consumption and Production" builds on the gains of the first two stages through the RDIs for effective clean technologies for water and energy sourcing, storage, and distribution. In this stage, reliance on water and energy supply should consider cybersecurity since these technologies and processes will need ICT and IoT. The fourth stage is geared towards "Universal Access and Security" scenario that can be reached when the drivers and opportunities unique to the cluster are managed harmoniously.

Considering the natural features of the country, the major drivers and opportunities in this cluster are shared with the other clusters, particularly the Environment, Climate Change and Space Exploration cluster, e.g., Seismic events and seasonal typhoons, exacerbated by climate change. Thus, floods and droughts can be experienced in different parts of the country. Local or regional planning and implementation for production and consumption rates are needed for both water and energy. Outbreaks of diseases in humans and other living organisms can be offshoots of water and energy problems such as in prolonged EL Niño and La Niña. Pollution from the land into the freshwater and marine waters constitute the significant threat to water safety. Physical changes in the watershed such as deforestation will negatively affect water availability.

Socio-economic drivers and opportunities also include population/demography changes and the shift in needs for water and energy coming from urbanization and economic growth. Planning and implementation should address uneven capacity of production-consumption rates and affordability at the local and regional levels. Independence of islands or regions in production capacity can result to overproduction in one and underproduction in another. Thus, measures must be undertaken to allow access to water resources at the inter-island or inter-region level.

At present and in the next few years the Philippines would have to make do with conventional technologies or enablers that will hopefully leapfrog to locally produced or adopted clean technologies soon. Available clean technologies for water and energy have been mostly developed in industrialized countries. To meet the present and future requirements of the country some of these clean technologies could be acquired via foreign direct investment, imports, and licensing arrangements. Further, these technology transfers involve importation of hardware and software, sharing of knowledge, and adaptation of technologies to local conditions. Tax incentives and other financial/economic support for business/industry or Public-Private Partnership or other future business/investment models are prerequisites to facilitate development of water and energy sectors. The "rule of law" should prevail in the access and distribution and water particularly in the underserved and unserved areas. Formal and informal science education from the earliest years could provide marked positive influences not only in the increase of S&T manpower but assist in making the Filipinos "science cultured" and "sustainability conscious."

Maintaining domestic water quantity and quality using indigenous technologies like rain harvesting can be enhanced by innovations in proper collection and storage. Local communities should be made aware of climate changes affecting the timing and amount of rainfall the excess of which can also result in flooding. Establishment and proper maintenance of water reservoirs in strategic places for domestic, irrigation, and electric generation should be given priority. Likewise continued improvements and wide use of locally available clean technologies for energy such as solar and wind energy should be supported based on a framework/space mapping that considers local hazards and risks.

Precision agriculture/aquaculture using an array of sensors linked with real time sensors for water quality and quantity would be a great boost to the sustainability and resilience of water supply. Biotechnology and nanotechnology will enable the development of these sensors and renewable energy. The development of manpower and infrastructure in this cluster should also be closely linked with the other clusters since the requirements for water and energy are universal and important in a circular competitive economy where wasteful and duplicating processes are minimized or removed.

The Blue Economy platform will play a pivotal role in this cluster and other clusters towards the achievement of "a prosperous, archipelagic, maritime nation" that is inclusive, sustainable, and competitive with healthy and productive citizens. The approach has dual objectives which are: the sustainable utilization of both living and non-living marine resources and the inclusive development of the people. The immense impact of the approach to coastal and oceanic transport, energy, sustainable tourism, fisheries and aquaculture/food security, habitat (land and water) protection, water supply (desalination) should be realized through a strategic/aggressive, whole-of government approach. A critical review of existing laws, policies and practices for appropriate revisions and/or simplification in support of the Philippine blue economy has to involve key representatives from maritime law and enforcement, marine science and education, maritime and other related businesses, and national security, among others.

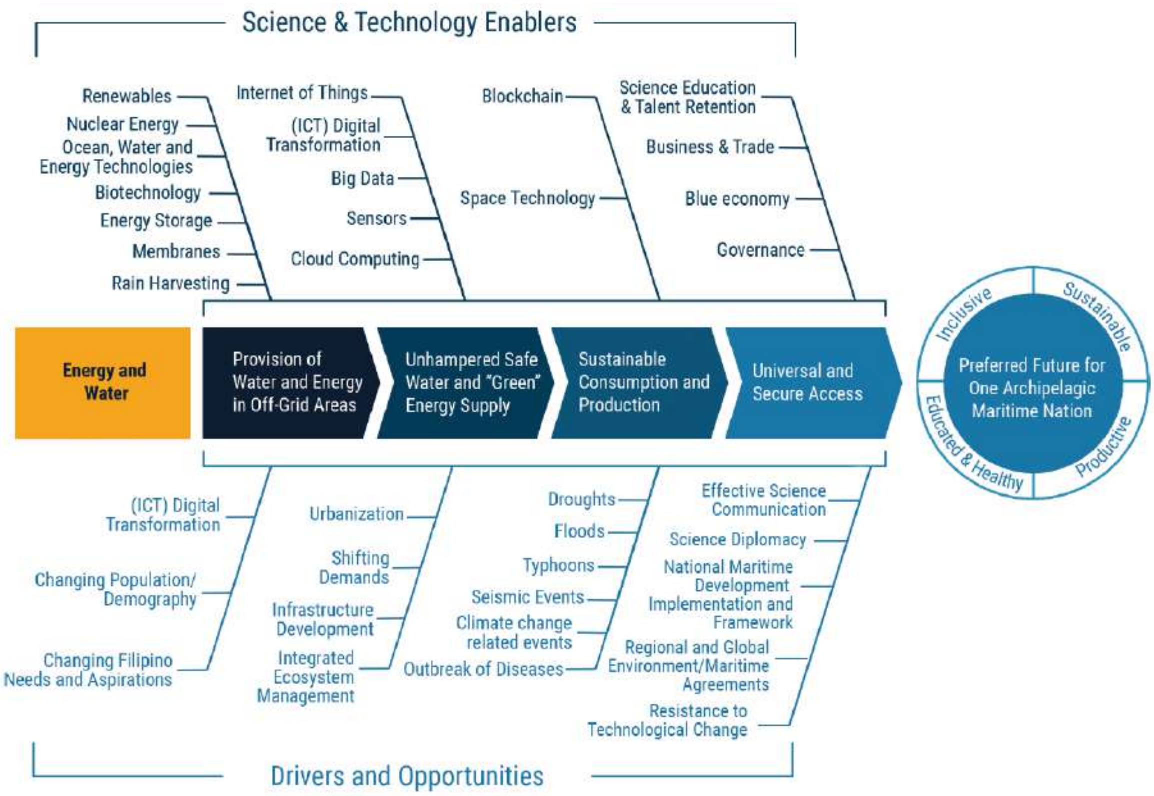


Figure 6.2_4. Energy and Water Cluster Map

Built Environments Cluster

As mentioned earlier in this report, the indicators used to measure poverty are based on counting the "individuals and families whose income fall below the poverty threshold as defined by NEDA and/or cannot afford in a sustained manner to provide their minimum basic needs of food, health, education, housing, and other essential amenities of life" (Mapa 2020). Based on the Family Income and Expenditure Survey in 2000, 2003, 2006 and 2009, the average percentage of the minimum income that is spent for non-food needs is only about 30% including expenses for housing, transportation, and communications. About 70% is spent for food (Mapa 2020). Thus, to enable communities to enjoy healthful, safe, and pleasant living conditions, concerns the provision for shelter and infrastructure must be addressed if we are to significantly reduce the incidence of poverty in the country. These concerns are embodied in RA 8425.

The initial setting of the Built Environments cluster (Figure 6.2_5) is the COVID-19 pandemic that has caused widespread suffering in all sectors and in all countries and exposed in a more pronounced manner, the weaknesses, and inequalities that have been lurking in our midst for many decades.

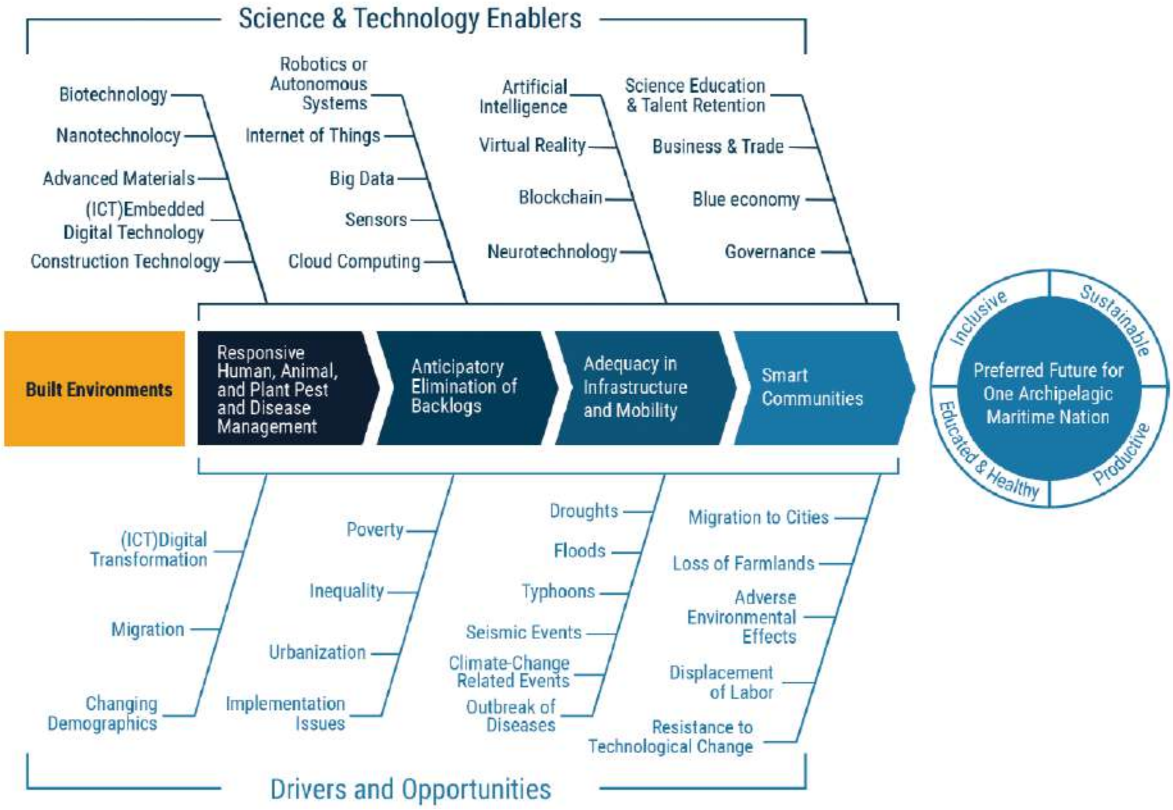


Figure 6.2_5. Built Environments Cluster Map

The challenge is for STI to provide the tools to responsibly manage the incidence of pests and diseases in humans, livestock, and poultry and in the food crops. The containment of the spread of these diseases should set the stage for the revival of the economy, followed by improvements in productivity to create new wealth in a sustainable manner. However, the water and power provision will be discussed in the scenario on water and energy.

Provision for safe and comfortable shelter engenders a sense of security for the Filipino family, whether they reside in urban or rural settings located inland or along the coasts. Likewise, civil infrastructure and transportation are critical factors in achieving economic efficiency, trade facilitation, and effective governance. This scenario will take into account the unique archipelagic and maritime features of the Philippines.

Civil infrastructure systems provide the lifeline of society. Human activities are supported by civil infrastructure systems or built environments that are managed, designed, and analyzed using the S&T tools. Civil infrastructure systems extend beyond civil engineering in order to construct safe and comfortable shelters in urban and rural settings, support economic activities and enable social interaction. Civil infrastructure systems deal with how the different built environments function together including electric power, fuel supply, water and wastewater distribution and management, communications, transportation, waste disposal, and shelter in urban and rural communities located inland or along the coasts and will harness the following STI areas:

- Engineering: civil, mechanical, electrical, chemical, sanitary, electronics
- Architecture
- Urban planning
- Sociology
- Chemistry
- Physics
- Biology
- IOT - detection of phenomenon using sensors, sending signals and responses, generating data for analysis
- Big Data - tools to measure massive amounts of data to gain insights, see patterns, and analyze e.g disaster risk management
- AI - attempt to migrate intelligence to machines, may trigger changes in modes of production, mindsets, and means of achieving social productivity
- New materials and nanotechnology - discovery of unique physical and biological properties of nano-scale matter with wide application in medicine , environment,energy, etc.
- Autonomous systems - automated vehicles, drones, robots
- Biotechnology - redesigning organisms to produce substances of economic value such as fuels, medicines, easily biodegradable biomaterials
- Structural dynamics design
- Resilience engineering
- Sensors
- Geographic information systems
- Spatial analysis
- Transportation systems
- Statistics
- Environmental science

Innovation Stage I: Responsible COVID-19 and Other Pests and Diseases Management - The Role of Built Environments and Digital Transformation

This innovation stage will operate in the COVID-19 pandemic setting. The challenge for the present is for built environments or civil infrastructure to mitigate the spread of COVID-19, as well as other pests and diseases that affect agriculture. Thus, the urgent task is to design and construct permanent or temporary built environments to support the timely containment and treatment of infectious diseases with the assurance that these public infrastructures are also safe for use during pandemics or natural disasters. This includes the retrofitting of rooms and grounds in schools so that students can attend school safely, the upgrading of hospital facilities, instituting measures in public transport and public places to enable compliance with physical distancing requirements. Due to restrictions in movement, it is also important to maintain the reliability of communications such as high-speed broadband to avoid disruption of transactions. Furthermore, wastewater disposal will be an important intervention to prevent the spread of infection and contamination. Currently, the Philippine government with the contribution of the private sector, is engaged in constructing additional healthcare facilities that comply with global standards.

A major effort will have to be initiated on the construction and retrofitting of shelters including homes and office rooms as this will require a large capital cost. Health protocols will have to be strictly observed in densely populated communities to minimize congestion especially in areas where there are many informal settlers living in single-room dwellings.

Observers note that the pandemic has hastened the adoption of technology-based strategies, notably ICTs, to cope with the unexpected disruption of activities (MIT 2021). The increase of online transactions, classes and meetings lessens face-to-face contact in order to control the spread of infection. Unfortunately, with large numbers of schools and business establishments shifting to online transactions and activities, the wireless telecommunications backbone has been unable to cope with the demand for more bandwidths. While adjustments are ongoing, the changes will not happen overnight.

During the pandemic, where lockdowns are frequently imposed, use of digital technology tools for identification, contact tracing, data gathering, financial transactions, and even the conduct of meetings has enabled the economy to function and social interactions to proceed albeit in a reduced manner. These tools should be made available to as many Filipinos as possible and access to quality wireless communication should be pursued relentlessly using a package of technologies.

The timely delivery of goods and services has been affected by the lockdowns as the transport services have been constrained to considerable downsize their operations. Moreover, the health protocols impose limits on the passenger load of the public transport system. The impact of this slowdown has been felt strongly by the micro, medium and small-scale enterprises and productivity remains low in business establishments, farms, factories, and the service sector.

Innovation Stage II: Revived Economy: Anticipatory Elimination of Backlogs

With the pandemic substantially controlled, this stage will revive and consolidate the gains achieved before and during the pandemic and attend to the backlog in the projects that have been delayed by the pandemic and other reasons. Previous initiatives that have been disrupted in various ways will be reviewed and those that will lay the ground for a high-growth development especially where significant progress has been achieved in the construction of vital infrastructure to enhance mobility and connect the islands in the archipelago.

Digital Transformation

The groundwork for digital transformation shall be intensified. Digital transformation"is the incorporation of modern technologies into an organization's processes and strategies to achieve business goals such as improving customer outcomes or operational agility" (MIT 2020).

The opportunities for innovation and stepping up digital capabilities are as follows (MIT 2020):

- Establishing a nationwide digital communications backbone that would reach all the islands and remote communities. This is to be coordinated with the energy sector with due consideration of operating microgrids.
- Improving the conduct of online learning- reinventing the way we learn
- Automating Manual Processes
- Accelerating Digital Capabilities of the citizenry
- Adopting a modern application development platform
- Using infrastructure or platform for IT security
- Expanding cloud services adoption
- Expanding agile and continuous-delivery methods
- Increasing investment in mobile applications
- Creating digital-first customer experiences
- Expanding application development teams

The digital transformation of Estonia is a model worth studying. After the Soviet Union was dismantled, the government of Estonia focused investments in digitalizing the public sector which allowed businesses to be registered and operated online to avoid the long processes required by the bureaucracy. This strategy generated jobs and tax revenue (Patricolo 2017; Pickup 2018).

It is expected that even after the restrictions of the pandemic have been lifted, remote work will still be the major mode of delivery of outputs by the workforce. The opportunities for innovation mentioned above are expected to keep businesses afloat through secure online workflow, and the development of continuous delivery applications for new products and services. These interventions are expected to rebuild the economy and set the stage of higher growth.

Shipping

Being an archipelagic country, the Philippines counts on the maritime industry to transport goods and services in both the domestic and global market. Shipping provides the major links among the islands of the archipelago. In a study made in 2006, water transport accounted for 42% of the freight in the country and in 2012, carried 74 million tons of cargo and 50 million passengers. Thus, with the lifting the post-pandemic, there will be opportunities to revive and improve maritime transport in the areas of domestic shipping, overseas shipping, upgrading of maritime manpower, shipbuilding and ship repair as well as the improvement and expansion of port facilities in cargo handling and the cold chain to service 8,112 seafaring vessels of various types that ply the Philippine seas (UN-ESCAP [date unkown]).

Shelter and human settlements

Responding to the housing backlog will be a great challenge during the recovery period. Increasing the production of houses at an affordable cost may have to be subsidized for selected beneficiaries. This could be complemented by mobilizing and generating financial resources to support end-users. (Padojinog 2020). While there are ongoing projects to provide housing for the low-cost segments, the backlog is still considerable at 5,880,630 units in 2015 inclusive of the socialized, economic, low, medium, and high types but not including 786,984 units for those who cannot afford. It is projected that by 2030, the total housing need will be 12.3 million units. (Padojinog 2016)

The goal is for S&T to provide the knowledge to innovate so that the cost of building houses/shelters will be affordable. This will involve the search for new materials from renewable sources and the discovery of new technology to produce cement with low carbon footprint. Furthermore, shelters should be intelligently designed to withstand the increasing frequency of extreme weather conditions and earthquakes. Highly populated living spaces such as condominiums have to be designed to provide more open spaces.

About the design of communities, especially in urban areas, the provision for walking, cycling and access to reliable and efficient public transport system have to be taken into account such that people, rather than vehicles, will be given priority for safe and healthy living. Furthermore, construction activity must consider the use of materials with low carbon footprint. Mass transport facilities and those the logistics to support the supply chain will benefit from well-designed, well-built roads, bridges, ports, and airports. All these to be carefully designed for resilience in the light of the occurrence of typhoons, floods, drought, and earthquakes. The durability of the materials used under tropical conditions must be subjected to tests and quality assurance. Preparations must be undertaken to cope with the production and maintenance of battery-powered electric vehicles.

Innovation Stage III: High Growth Development: Adequacy in Infrastructure and Mobility

The recovery phase has provided the foundation for high growth. Gains in the digital transformation of the economy and in governance will have established efficient systems of workflow. Efficiency will be the hallmark of the third phase of innovation.

High growth initiatives in digital transformation shall consist of the following including those cited earlier (MIT 2020):

- Sustained development of a nationwide digital communications backbone that would reach all the islands and remote communities. This is to be coordinated with the energy sector with due consideration of operating microgrids
- Automating Manual Processes
- Accelerating Digital Capabilities of the citizenry
- Adopting a Software-defined network
- Accelerating cloud migration
- Adopting a modern application development platform
- Expanding a multi-cloud strategy
- Using infrastructure or platform for IT security
- Expanding cloud services adoption
- Expanding agile and continuous-delivery methods
- Increasing investment in mobile applications
- Creating digital-first customer experiences
- Instituting "secure-by-design" application development
- Adopting a "cloud-first" application policy
- Expanding application development team

These developments in the digitalization of the economy are expected to accelerate the growth of agriculture, industry, and the services, with innovations supported by a vigorous R&D program in government and the private sector. The workforce shall deliver their outputs enthusiastically, knowing fully-well that their minimum basic needs are seriously attended to by the government and the private sector.

Backlog in housing, construction of ports, airports, road networks, and bridges shall have been significantly corrected with technologies that have a considerably lower carbon footprint.

This third phase of innovation will harness the highly trained critical mass of the workforce to sustain the momentum gained in the recovery phase with regard to shelter, transportation, and infrastructure. A maritime highway that links every part of the archipelago will enhance the participation of more communities in productive economic activities. Traffic flow of air, sea, and land transport shall be professionally managed and considerably improved. This maritime highway could possibly be linked with the proposed ASEAN maritime highway that is highly connected by a series of ferries and roll-on-roll-off transport mode.

Satellite-based remote sensing technology will monitor in real time air quality, water quality, population density, land use, food production, the extent of damage during typhoons, floods, earthquakes, and many other future applications.

Finally, trade shall have been facilitated by a digitally transformed work environment with timely-access to information coupled with a globally-accredited national quality infrastructure including internationally-recognized testing laboratories.

Innovation Stage IV: Competitive Economy: Smart Communities

A competitive economy will thrive only where its workforce lives in communities that are secure, safe and healthy, designed to be resilient to natural disasters, climate change, pandemics, and various ecological crises. By 2050, these communities, in urban and rural settings, coastal or inland, should protect people’s lives, sustain development gains, and drive positive change towards a future that is inclusive and prosperous. Smart communities have strong emergency response capacities in the form of support for planning, governance, capacity-building, funding, continuity of business, and delivery of services (Global Forum on Human Settlements 2020).

Smart communities are nature positive and climate-friendly, able to promote healthy lifestyles by strengthening the communication between stakeholders and government especially in the collection and analysis of data that will be the basis of important decisions. Food supply is critical and must not be disrupted even the times of economic downturns caused by pandemics and ecological emergencies.

Natural disasters and health crisis affect people the most especially those in coastal villages and the urban informal settlers. Thus, their living conditions must satisfy the minimum basic needs including healthful and safe shelters, reliable, secure, and well-maintained transport system and a sustainable civil infrastructure providing power, water, and access to the supply chain through strategically located roads and bridges.

A one-size-fits-all approach to the establishment of smart communities will not work. Future oriented studies on smart communities should consider the unique spatial (geographic and environmental) attributes, social, cultural, and economic factors. This will require a multidisciplinary approach involving S&T inputs, especially from the social sciences.

Smart communities must comply with the key principles of a circular economy(Global Forum on Human Settlements 2020):

- waste and pollution to be designed out of products and the living systems
- materials durable enough to be kept in use for as long as possible
- a regenerative surrounding natural system with adequate open outdoor spaces

These attributes are people-centered, sensitive to the mutual aspirations of the stakeholders. Special mention is made for communities along the coasts who derive their living from the ocean and aspire to live with the ocean in a sustainable manner.

A competitive economy is derived from a resilient and agile future that is dependent on S&T inputs to integrate people, water, nature, and the built environments. These are constructed ecosystems reinvented to support the well-being of all (Global Forum on Human Settlements 2020).

Towards an Integrated STI RoadMap

The integrated map (Figure 6.2_1), cognizant of the impact of the COVID-19 pandemic, combines all the clusters and their respective goals, from responsive human, animal and plant pests and disease management to a competitive economy. The progress of each cluster is determined by the interplay of S&T enablers and drivers and opportunities. Achievement of a competitive economy across clusters would bring the Philippines to its preferred future for a prosperous, archipelagic maritime nation that supports a technology-explicit development agenda that is inclusive and sustainable and nurtures a citizenry that is educated, healthy, and productive.

Launching the Priority STI Interventions in Support of an Archipelagic and Maritime National Development Agenda

Here are some suggested initial priority activities to be started in the recovery and revival phases of the STI roadmaps to consolidate and enhance the gains in STI highlighting the need for an archipelagic and maritime oriented national development agenda:

- Building a sustainable critical mass of STI human resources
  - Develop, attract, and retain expertise in dealing with the unique geographical features of the Philippine archipelago
  - Develop, attract, and retain expertise in marine science and related sciences
- Create the Philippine Council for Maritime, Marine and Aquatic Resources Research and Development (separate from PCAARD)
- Develop a focused R&D and extension program in maritime and marine sciences
  - Shipbuilding and drydocking
  - Transport Studies to achieve cost-effective efficiency
  - Mapping
  - Fisheries - modernization of fishing boats guided by GPS towards rich fishing grounds

    - High valued products from biological resources from the sea (drugs, food, food additives, cosmetics, flavors, colorants, etc.)
    - Inventory of biodiversity of our oceans and the archipelagic land mass
    - Energy - wave, ocean thermal
    - Mineral resources
    - Desalination for domestic water use
    - Pollution control
    - Demographics, economic, and educational profile of coastal village
    - Pollution control and abatement especially of tourist spots along the coast
    - Reclamation studies
    - Maritime safety and rescue system
- Develop a focused R&D and extension program to link and characterize with precision the biotic and mineral resources of our archipelagic land masses
    - Inventory of biodiversity (flora and fauna)
    - Inventory of mineral resources
    - Expanding the nautical highways
    - Deployment of ports and airports
    - Land use planning
    - Management of freshwater resources including pollution control and abatement in the major waterways and lakes; collecting rainwater
    - Urban and rural human settlements planning
    - Power distribution
    - Telecom infrastructure
    - Planned transport infrastructure to enhance correspondence in schedule of air, land, and sea transport services
    - Land degradation

DIGITAL ARTWORK

Space Karakoa

Primary conceptual idea by Julius Sempio
Art by Jerome Suplemento II

The Philippines' scientists, engineers, and future astronauts will have vital roles to play in the future of space exploration, as all the world's nations inexorably move to develop space science and technology to meet the needs of the global population. The Philippines' abundance of natural, cultural, and intellectual resources can serve to inspire and inform new technologies. Here we envision a space station that resembles the karakoas of centuries past, built through international cooperation using the expertise and knowhow of Filipino space scientists and engineers.

Disclaimer: The views and opinions expressed in the artworks do not necessarily reflect the official policy or position of the NAST PHL.

SECTION 7

Ensuring Continuity and Relevance

PERIODIC REVIEWS OF THE FORESIGHT

Foresight as a long-term policy instrument merits regular review and updating if it is to remain relevant to the times. Casssingena-Harper (2003) underscores the importance of the foresight review process and the concerns to be addressed:

"The foresight process involves intense iterative phases of open reflection, networking, consultation, and discussion leading to the joint refining of future visions and the common ownership of strategies, with the aim of exploiting long-term opportunities opened up through the impact of science, technology, and innovation (STI) on society… It is the discovery of a common space for open thinking on the future and the incubation of strategic approaches… in this sense the foresight process has no beginning or end, since it builds on previous and ongoing conversations and consultations and sets in motion learning curves and other intangible spin-offs which are not easily captured in short timeframes…"

Three basic tenets for a rigorous evaluation of foresight have been proposed (Georghiou 2003):

- Accountability - efficiency in the conduct of activities and proper accounting of public funds
- Justification - whether the impact justifies the continuing conduct of foresight
- Learning- improvements in the foresight process and scope

Institutionalizing the Foresight System in Other Countries

Various approaches have been used in the evaluation of national foresight activities as follows (Public Service Foresight Network 2017; Georghiou 2003):

- Singapore: Centre for Strategic Futures in the Prime Minister's Office Strategy Group
- United Kingdom: Horizon Scanning Program in the Government Office for Science
- Germany: Chancellor's Office encourages and facilitates dialogue Periodic Reviews of the Foresight 2040 and capacity-building; Futur initiative
- France: Centre strategique in Prime Minister's Office; several think tanks
- Finland: Prime Minister's Office conducts foresight studies and coordinates foresight in departments
- Japan: National Institute of Science and Technology Policy (NISTEP)
- Korea: Korea Institute of S&T Evaluation and Planning (KISTEP)
- Australia: CSIRO has a ten-person foresight team
- Denmark: Prime Minister chairs a "Disruption Council" composed of seven ministers and 32 stakeholders
- China: State Council and National Development and Reform Commission

The different approaches are used by governments in the conduct of foresight activities. The extent to which foresight is institutionalized differs presumably due to the unique characteristics of their administrative culture, human, and financial resources.

As discussed in previous sections, foresight is conducted to inform and develop policy and influence the direction of the national innovation system. Cassingena-Harper (2003) contends that the foresight activities involve "the discovery of a common space for open thinking on the future and the incubation of strategic approaches… in this sense the foresight process has no beginning or end..." and therefore is in a continuing process of refinement.

Thus, the institutionalization of foresight must be seriously considered even if such would proceed gradually into full integration in governance. The refinement of vision and strategies is the core function of foresight and the mechanism by which foresight can influence outcomes is by constant review of the issues and concerns that have been anticipated and whether such have matched the current realities. The discernment of patterns trends, drivers, science and technology frontier areas, uncertainties including the emergence of black swans are vital to the formulation of resilient and agile response modes.

Institutionalization of the Philippine Foresight

In order for long-range plans like PAGTANAW 2050 to yield the desired results, there must be continuity—this Philippine foresight spans three decades. It must remain relevant and continue to provide both vision and guidance across five Presidencies and the administrations that are part of these changes in leadership.

For this to be possible, there must be STI foresight institute tasked solely with the continuity and relevance of the initiatives detailed in this STI foresight, one that will remain focused on the job despite upheavals in the political environment, as well as in changes in government policies.

Such an STI foresight institute will, essentially, *provide a steady base from which policymakers and government functionaries may build the needed support systems, infrastructure, and policies—as well as adjust the same when needed. PAGTANAW 2050 must also provide a strong representation of all stakeholders in the process of bringing this Foresight from planning to execution and evaluation, and, as necessary, recalibration.*

Each section and operational area of this Foresight deals with different communities of stakeholders in vital areas, such as education, food security, environmental matters, health care delivery, sociopolitical developments, and so forth. Each segment of the STI foresight is inextricably bound to the others— just as we are all, in some way, bound to each other as part of a nation and the society within it.

Creating an institute to ensure the continuity of efforts to take this STI foresight from the drawing board to the physical world will go a long way to making certain that the goals and aspirations set to paper here will become actual realities.

Such an institute will need full time core staff and harness the expertise of the academe— including the scientists who have generously given their time, expertise, and efforts to produce the work included in this Foresight.

An Advisory Committee to provide guidance to the STI foresight activities may be organized with representation from ranks of stakeholders, policymakers, and the communities that each foresight segment will affect, as well as functionaries of government from agencies that will be part of the planning and implementation of the initiatives proposed in this Foresight.

Responsibilities of the STI foresight institute

The institute would be responsible for, but not be limited to, the following:

- Providing timely anticipatory "intelligence" on the developments in STI that are taking place locally and globally, the future challenges and options as inputs to decision-making, policy formulation and budget planning and implementation.
- Collaborating with foresight institutions in the Philippines and abroad to gain awareness of trends and drivers of change
- Providing representation of the STI stakeholders, and strong two way communication linkages between the committee and the communities they represent.
- Developing ways and means—including existing ones—to engage the people in public consultations, such as town hall discussions, of the proposed initiatives in this STI Foresight.
- Studying how specific STI stakeholders (i.e., local government units, schools, private sector establishments and organizations, government agencies, government owned and controlled corporations) can contribute to the projects and initiatives of the institute.
- Setting timelines for short-, medium-, and long-term goals like the United Nations' Sustainable Development Goals that will serve as benchmarks for progress of this Foresight and its resulting programs, initiatives, and advocacies that will be designed based on it.
- Maintaining continuous documentation and record-keeping of processes, initiatives, policies, and legislation that results from this Foresight, as well as keep records of the implementation of the same for public reference.
- Convening regularly to check the benchmarks for progress of the public consultations on, implementation of and the results of initiatives proposed under this Foresight.
- Engaging policymakers from government and the private sector in a continuing conversation about STI foresight, its proposals, benchmarks, and results so that the foresight initiatives will remain steadily on track across the foresight timeline.
- Providing regular reports on the progress of this Foresight to the public through media, social media, and other means at its disposal.
- Being available to all stakeholders so it may address any concerns over the policymaking and implementation processes of STI foresight.

For continuity to be possible, the proposed STI foresight institute must be insulated from the political upheavals that have disrupted the continuity of other efforts by the government in the past. There can be no short-term political agendas, nor big business manipulations of the institute for continuity.

Rather, the STI foresight institute must be the bedrock upon which this Foresight will stand, that it might last the 30 years it projects. Instead of being influenced by the erstwhile politics that will undoubtedly surround it, the STI foresight should provide a strong framework into which efforts by government at all levels, the private sector, industry, and communities can be integrated.

The STI foresight institute will have set tenures for its core staff, and ensuring their inclusion on the basis of their track records in their respective fields of endeavor, to serve the best interests of the Filipino—and not any one group of persons or organizations alone. There is much work to be done if we are to take this Foresight and create the best possible benefit for our people, and our nation. The institute that will oversee this work must be made up of the best minds available and have both the drive and the integrity to see the work through.

Foresight Lessons from Great Minds

Dr. Jose P. Rizal (1889) has observed that “[R]eforms which have a palliative character are not only ineffectual but even prejudicial, when the government is confronted with evils that must be cured radically. And were we not convinced of the honesty and rectitude of some governors, we would be tempted to say that all the partial reforms are only plasters and salves of a physician who, not knowing how to cure the cancer, and not daring to root it out, tries in this way to alleviate the patient’ s sufferings or to temporize with the cowardice of the timid and ignorant.”

The changes that must be made across this Foresight would rank among the radical ideas that Rizal wrote about. This Foresight seeks more than “plasters and salves” for the many things that ail our country that can be addressed with science and technology—and any institution that will ensure the continuity of the proposals recorded in this Foresight must have the “honesty and rectitude” Rizal demanded then, for the work before it will be no less difficult than that of a physician seeking to cure cancer in his or her patient.

The STI foresight institute and advisory committee must also be capable of transcending the changes in the country’s political landscape and must be impervious to the influence peddling those with vested interests can bring to bear, should those vested interests clash with the interests of the nation and its people.

As the National Artist for Literature Nick Joaquin (1966) points out: “An honest reading of our history should rather force us to admit that it was the colonial years that pushed us toward the larger effort. There was actually an advance in freedom, for the unification of the land, the organization of towns and provinces, and the influx of new ideas, started our liberation from the rule of the petty, whether of clan, locality or custom.” Not everything learned from centuries of existence as a colony is to be dismissed out of hand. Rather, if one is to take the lessons of history objectively, then one stands to learn clearer and more useful lessons.

Joaquin underscores the need for better and stronger social organizations, with more worthy goals than those common in the small tyrannical fiefdoms our country has been engaged in for much too long. In both the manner of writing this essay, and its content, Joaquin asks us to take a long, objective look at the cultural and historical points he makes so that we can surpass the heritage of smallness he sets down on paper.

Paul D. Hutchcroft and Joel Rocamora published their essay "Strong Demands and Weak Institutions: The Origins and Evolution of the Democratic Deficit in the Philippines" in the Journal of East Asian Economics (Hutchcroft and Rocamora 2003). That piece unpacks the systematic problems that explain weaknesses in the country's governance systems that must be seen and addressed: "Over more than a century—from the representational structures of the Malolos republic of 1898 to the political tutelage of American colonial rule, from the cacique democracy of the postwar republic to the restoration of democracy in the People Power uprising of 1986—Filipinos know both the promise of democracy and the problems of making democratic structures work for the benefit of all. Some 100 years after the introduction of national-level democratic institutions to the Philippines, the sense of frustration over the character of the country's democracy is arguably more apparent than ever before."

In their essay, Hutchcroft and Rocamora (2003) also wrote of the "capacity of many elements of civil society to demand accountability and fairness from their leaders" even as they pointed out "the continuing failure of democratic structures to respond to the needs of the poor and excluded. Philippine democracy is, indeed, in a state of crisis."

Hutchcroft and Rocamora write that "[w]hen we speak of a 'crisis' of Philippine democracy, it is important to emphasize that the fundamental values of democracy continue to command broad respect from all sectors of Philippine society. The crisis is manifested, rather, in a deepening frustration over the inability of democratic institutions to deliver the goods, specifically goods of a public character."

The matters raised by Rizal, Joaquin, and Hutchcroft and Rocamora are all things we must still take stock of as this Foresight's proposals are considered and put into practice, for they are still definite areas of concern in the society where this Foresight will be put to use. We must go beyond simply being hurt by the observations these four authors have made—we need to understand exactly what they are saying so that these can guide us as we take action on these weaknesses in our societal and governmental systems. That way, we can make the changes that are necessary for the continuity of growth for our country and our people using this Foresight.

The proposed institute for continuity, and our policymakers in whose hands this Foresight sits, must consider the painfully sharp observations made in these three essays as they decide how to move forward with this Foresight.

FORESIGHTING EXERCISES WITH ASEAN AND BEYOND

While each country benefits individually from foresight exercises within their states and national borders, we live in a world where international cooperation offers opportunities to accelerate growth and progress.

Harnessing science, technology and innovation on a regional level, such as across the Association of Southeast Asian Nations (ASEAN), would facilitate such work immensely. This would call for a good framework in diplomacy, as well as science and technology, and in communications within and between each member-state in the region. Such an effort especially by the proposed STI foresight institute will take a multi-disciplinary approach that offers benefit to all.

O'Doherty and others (2020) explain that such a process would:

- Inform policymaking so that key actors are more aware of longerterm scenarios, are more prepared for different possibilities, and able to recognize an emerging scenario and its wider implications.
- Help build networks among the people centrally involved with shaping the future. Bringing people together – perhaps virtually – will facilitate collective sharing of visions and assessments of the future, help understand challenges and opportunities, and provide a basis for formulating strategies and objectives.
- Develop capabilities that shape a 'foresight culture'. This should enable individuals and groups to define and embark upon more detailed foresight activities and to forge their own foresight networks.

Vital Partnerships

The United Nations holds a similar view of international and regional cooperation, especially in light of the COVID-19 pandemic: "Few countries alone will be able to achieve the SDGs with business as usual" (UN IATT 2020). In that guidebook, it is noted that "many countries are going to fall far short of other goals as well," and goes on to recommend that the "effective use of STI may change the trajectory and accelerate progress toward the future we want, particularly if developing countries are able to benefit more from international partnerships."

Pooled resources and shared burdens make the work of creating progress and prosperity easier—especially among nations that share common topographical, geographical and seasonal features, as well as cultural aspects that help encourage cooperation. Shared interests—including but not limited to regional security, food security, resource and environmental preservation, the promotion of public health initiatives and educational initiatives—can be given the manpower, resources and support they require if a healthy exchange of expertise, learning, experiences, and understanding of these things can be achieved within the ASEAN region.

Challenges

According to the guidebook, there are "a large number of both existing and emerging technologies that present not only many opportunities but also many challenges for developing countries," including digital technologies (such as the internet, artificial intelligence, robotics, remote sensing, big data analytics, blockchain, 3-D printing), nanotechnology, new materials, and biotechnology."

Thus, the need for regular regional foresighting exercises among the ASEAN member-states—exercises that will link the individual STI foresights of these nations together along pathways that will help these member-states work together so they can achieve their goals, individually and regionally, through international cooperation and through linkages across their industries and private sector groups.

Addressing Inequalities

To most effectively map out and engage in Foresighting with other nations, especially our ASEAN neighbors, we need to understand the nature of the inequalities that hamper our progress.

The United Nations Conference on Trade and Development (UNCTAD) report (2020) stated that "rapid economic growth in emerging economies has fueled the rise of a global middle class. Nevertheless, there is persistent poverty, and rising inequality. Wealth is highly concentrated, and there are also large disparities in income-earning opportunities, as well as in standards of education and health. These imbalances constrain economic growth and human development while heightening vulnerability, whether to pandemics, or economic crises or climate change — and can soon destabilize societies."

The matter of inequality, according to the UNCTAD report, "is also affected by technological revolutions. Technological changes combine with financial capital to create new techno-economic paradigms — the cluster of technologies, products, industries, infrastructure and institutions that characterize a technological revolution."

A regional cooperation to enter into Foresighting exercises will go a long way toward addressing such inequalities, and it will provide a better pool of resources for the implementation of initiatives taken from their national foresight exercises, as well as a regional foresight.

There is much common ground from which we can build a stronger region by sharing resources and efforts to create the progress each nation needs. Working together on a regional foresight endeavor would make good use of these strategic advantages our nations enjoy. From there, we can build up to making use of our learnings and experiences to building foresight exercises with other nations and regional.

CONCLUDING STATEMENTS

Progress towards a Prosperous, Archipelagic, Maritime Nation should not remain a dream for the Philippines, with its rich natural and human resources. However, such growth has stayed in that realm of wishful thinking for the lack of continuity in government's efforts for generations, as well as the lack of systems that would enable—and encourage—Filipinos to participate effectively and fully in such efforts.

Perhaps an explanation for this can be found in the work of National Artist for Literature Nick Joaquin, who penned an essay titled "A Heritage of Smallness" in 1966 under the nom de plume Quijano de Manila, where he made several painful observations about the ways Filipinos put obstacles in their own way (Joaquin 1966).

This excerpt from the essay Joaquin is apt, if hard to acknowledge: "The barangays that came to the Philippines were small both in scope and size. A barangay with a hundred households would already be enormous; some barangays had only 30 families, or less. These, however, could have been the seed of a great society if there had not been in that a fatal aversion to synthesis. The barangay settlements already displayed a Philippine characteristic: the tendency to petrify in isolation instead of consolidating, or to split smaller instead of growing."

Joaquin also wrote: "The depressing fact in Philippine history is what seems to be our native aversion to the large venture, the big risk, the bold extensive enterprise."

In his essay, Joaquin noted: "We would deliberately limit ourselves to the small performance. This attitude, an immemorial one, explains why we're finding it so hard to become a nation, and why our pagan forefathers could not even imagine the task."

This is a long-standing mindset among our people that must change if we are to succeed in a world that is constantly disrupted by rapid technological changes that provide fresh opportunities for growth.

Why quote a National Artist for Literature in this Foresight if all he has to say is critical of both the people we seek to serve and the government?

The keen eye of the journalist and writer Joaquin offers in his 1966 essay provides us with valuable insights: "Our cultural history, rather than a cumulative development, seems mostly a series of dead ends. One reason is a fear of moving on to a more complex phase; another reason is a fear of tools. Native pottery, for instance, somehow never got far enough to grasp the principle of the wheel. Neither did native agriculture ever reach the point of discovering the plow for itself, or even the idea of the draft animal, though the carabao was handy. Wheel and plow had to come from outside because we always stopped short of technology."

This three-decade Foresight is one of those bold enterprises our esteemed National Artist for Literature Nick Joaquin wrote about, and, while we may hope to be able to answer Joaquin's criticisms with it, we must ensure that this large venture succeeds, and continues to do so, across its' set timeframe.

Such is also a recurring fate of many initiatives of government that have lost steam—across agencies, administrations, and at all levels from the barangay to the Palace. Just as science and technology permeates daily life, so, too, do media and the arts—and the insights of our journalists, authors, and artists often provides valuable social commentary that has direct and strong bearing on the state of our nation at any given point in time. What this Foresight must take into account is that it will be implemented in the physical and political reality of a nation that has always had the potential for great growth but has not yet fulfilled that potential. Painful truths only hurt until they are addressed, which is why we need to read and comprehend such truths, then act on them accordingly.

To answer Joaquin's criticisms, we need to do more than spew angry, defensive retorts. He did not simply mean to rile his readers with his essay. He penned this as a call to action, by speaking truths that should be taken as a complex challenge, rather than as a set of put-downs. Joaquin was mapping the societal and political landscape to show his readers where the pitfalls have always lain. It is up to us to learn the lessons he has sought for decades to teach.

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APPENDIX

LIST OF TECHNOLOGIES PER OPERATIONAL AREA

Operational Areas	Specific Technologies
Food Security and Nutrition	• Remote sensing • Artificial Intelligence • Big data system • Nanotechnology • Transgenic technology • Biotechnology • Transport and logistic system • Online platforms and internet-based solutions • ICT-based farming • Digital farms • High-pressure hydraulic systems • High-speed, high precision equipment • Genetic breeding • High throughput phenotyping • Tissue culture/embryo rescue • Bioinformatics • CRISPR-CAS • Genomic selection
Health Systems	**Health Information Technology** • EHR / Health information system • Telehealth platforms • Artificial intelligence • Data analytics • Internet connectivity • Disease tracking • Knowledge management • Precision medicine • Accessible public health databases • Biomedical devices **Health Policy and Systems Research** • Clinic management system • Primary care algorithm • Vaccination program • Cost effectiveness evaluation system • Government policy • Health informatics programs • Health technology assessment • Implementation science • National health indicators **Precision Public Health** • Omics technology • Precision medicine • Genome database; access • Artificial intelligence • Vaccination program • Programs for affordable drugs • Health information system

Operational Areas	Specific Technologies
	Health Literacy • Public health education, information • Digital platforms, electronic system • Gamification • Mobile health • Community engagement • Telehealth **Health Financing** • Blockchain technology payment system • Attractive compensation for healthcare workers • Efficient collection of sin tax • Health informatics • IT architecture/telecon backbone • Research and development budget allocation • Automated claims reimbursement system • Real-time socialized payment scheme **Biotechnology** • Locally manufactured devices • Rapid and molecular diagnostics • Wearables and sensors • 3D printing • Robotics • Natural products and therapy • Genomics • "Nanobiotechnology" • Regenerative medicine; stem cell technology • Assistive and supportive devices **Health Workforce Enhancement** • E-learning platform, online learning, MOOC • Manpower database • Virtual /augmented reality; use of robots for training • Remote screening and monitoring of healthcare workers • Diagnostic system for physicians • Information system records • Proper compensation of healthcare workers • On-demand learning modules **Environment** • Green architecture • Health waste management, disposal, recycling • Biosensors for environment • Antibiotic resistance monitoring • Health impact assessment • Risk mitigation devices • Artificial intelligence • Vaccination program • Training of specialists • Policy environment
Energy	**Clean Energy Technologies** • Solar energy technologies and systems • Wind energy technologies and systems • Clean Energy from ocean waves • Energy storage • Smart energy systems • Micrograds • Energy blockchain and IoT • Biofuels • Energy from wastes • Energy recovery devices **Nuclear Power**

LIST OF TECHNOLOGIES PER OPERATIONAL AREA

Operational Areas	Specific Technologies
Water	**Rainwater harvesting** • Small-scale water cisterns to collect rainwater in households • Water reservoir through groundwater aquifer with infiltration galleries at strategic recharge areas • Infiltration gallery built around the house to deep percolate into the ground (subsurface) to minimize flood risk in case storage tanks for rainfall are full **Seawater desalination with electricity production** • SWRO integrated with pressure retarded osmosis and forward osmosis **Algae-based wastewater treatment** • Fluidized bed algae-based wastewater treatment system • Fixed-bed algae-based wastewater treatment system • Suspended algae-based wastewater treatment system **Membrane technology** • Membranes with high chemical stability for wastewater recovery • Membranes and modules with antifouling properties • Large membrane surfaces with homogeneous characteristics • Desalination of sea water **Nutrient recovery from wastewater** • Biological assimilation through constructed wetlands for phosphorus and nitrogen removal from wastewater • Nutrients recovery by microalgae-based processes **Smart water monitoring** • Real-time remote water level or soil-moisture monitoring device • Smart water quantity meter • Smart water quality meter • Internet of Things • Sanitation and sewerage management system technology • Periodic and iterative assessment of the water quality and pollution technology **Constructed wetlands and phytoremediation** • Phytoextraction or phytoaccumulation • Phytovolatilization • Phytostabilization or Phytosequestration • Phytodegradation • Phytofiltration or Rhizofiltration or Rhizodegradation
Environment and Climate Change	**Agricultural Lands** • Precision agriculture (i.e., precision fertilization, irrigation, and pest and disease detection and management) • Site-Crop suitability matching tools • Remote Sensing for the monitoring of soil conditions. • GIS-Aided Pesticides and Fertilizer Use Information system to keep track of the amount and location of application of pesticides and fertilizers for the assessment of environmental impacts **Watershed** • Comprehensive long-term watershed and ecosystem observation systems–continuously track down the changes in its functions and services, along with the associated changes in the natural (e.g., climate) and socioeconomic drivers (e.g., land use). • Philippine Ecosystem and Watershed Observation Network–adopt protocols of existing international observation networks such as NEON (National Ecological Observation Network of USA), TEAM (Tropical Ecology Assessment and Monitoring), and ILTER (International Long-Term Ecological Research Network). • Philippine Ecosystem and Watershed Observation Network–adopt protocols of existing international observation networks such as NEON (National Ecological Observation Network of USA), TEAM (Tropical Ecology Assessment and Monitoring), and ILTER (International Long-Term Ecological Research Network). • Environmental and biological sensors–monitor hydrological processes and soil conditions. • Remote sensing, drones and related technologies–facilitate real-time data collection concurrently over many watersheds and ecosystems that will allow for comparative and relational studies across watersheds and ecosystems in different biogeographic zones. • Watershed decision support systems–processreal-time and quasi real-time datasets into information that are vital to making sound science-based management and policy decisions.

Operational Areas	Specific Technologies
	• Watershed and ecosystem models–projection and simulation of watershed and ecosystem responses to changes in climate and development activities • Land use scenario builders–projection of expansion of urbanization, agriculture, land degradation, and deforestation **Coastal and Marine Resources** • Subsea engineering and technology • Sensors and imaging • Satellite technologies • Computerization and big data analytics • Autonomous systems • Biotechnology • Nanotechnology • Drones • Autonomous underwater vehicles (AUVs) • 3D mapping and modeling tools • High resolution and nano satellite imagery, • Suite of monitoring and surveillance tools • Geospatial technology. e.g. remote sensing, geographic information science and spatial statistics. **Soil** • Nationwide reassessment of soil resources and setting in place of an integrated decision support system (DSS) consisting at the least of systematic and continuous monitoring of soil health. • Web-based soil and related dataset management system • Widely and readily accessible multiple platform-based soil health assessment tool **Land** • Application of landscape-based (i.e., watershed and ecosystem-based, and ridge to reef approach) local and regional land use planning and development, and agricultural development, and landscape/ecosystem-based. • Practice of sustainable land management (SLM), sustainable forest management (SFM) and multifunction forest landscape restoration, landscape-seascape management and sustainable agriculture (SA) including precision agriculture. • Inherent to the integrated approaches to land use planning and management for robust tradeoff analysis between competing land uses in terms of individual and combined net impacts on ecosystems, environment, economy and social welfare. **Timber** • Robust timber resources tracking system • RFID-aided forest products tagging and tracking technology **Forest and Biodiversity** • Remote sensing and GIS-aided precision tools for the stratification of areas. • ICT for general or targeted IEC programs. e.g. cellular phones and tablets. • Personal digital assistants (PDA) • Electronic diaries • CyberTracker • Species distribution models • Habitat fragmentation analytical tools • Animal Camera Trapping Technology **Climate Change** • Technologies for adjusting cropping calendar, developing flood tolerant rice varieties, diversification of crops and livestock. • Tailor-made adaptation tools and technologies focused on food security, soil and water conservation, resilience of terrestrial, coastal and marine ecosystems, biodiversity and land productivity, and human security. • Nature-based solutions • Real-time online climate monitoring and forecasting dataset and information system of PAGASA freely accessible to the public at will for informed response actions to climate related risks.

LIST OF TECHNOLOGIES PER OPERATIONAL AREA

Operational Areas	Specific Technologies
Shelter, Transportation, and Other Infrastructure	**Digital Technologies** • 3D printing or additive manufacturing of materials • Active energy-response building cladding or window technology, including electrochromics and thermochromics • AI tools to monitor impact of infrastructure development to economic cost and well-being of communities • Automatic small-freight transportation system using underground spaces and building conduits • Autonomous vehicles • Battery-free wireless communications • Building information modelling systems • Decision-making software to support the optimization of building maintenance • Demand-responsive domestic appliances • Digital floor plan-based automatic high-rise building construction robots • Energy self-sufficient megabuilding design construction technology • Flying cars • Food storage, packaging, and distribution facilities • High-speed vertical-horizontal 3D track system in high-rise-buildings-underground spaces • Household waste collection/transportation/categorization system for recycling or energy-recovery • Hyperloop transport • Hypersonic airplanes • Internet of Things, Internet of Everything • Maglev trains • Modularization-based LEGO-type one-day housing construction technology • Passenger health monitoring systems • Real-time continuous disaster-monitoring technology using remote sensing information of multiple satellites • RFID tagging and tracking systems • Robot inspection technology to inspect buildings or infrastructures that are more dangerous or costly for humans to inspect • Safety communications systems • Seismic damage prediction systems • Shelters and emergency facilities • Smart grid energy monitoring, networking, distribution • Smart water monitoring • Traffic control systems • Unmanned low-altitude aircraft for the surveillance of territorial waters, disaster monitoring, and rescue support **Nanotechnologies** • Aerogel insulation • Carbon conversion, sequestration, storage in building materials • Carbon fiber bodies • Nano-energy generator • Nanotech improved LED lightbulbs • Photovoltaic cell • Pressure and motion sensors • Quantum dot vision windows **Biotechnologies** • Biofuels • Bioluminescent lighting • Multiple biometric recognition • Food storage, packaging, and distribution facilities **Neurotechnologies** • AI tools to monitor impact of infrastructure development to economic cost and well-being of communities • Multiple biometric recognition • Passenger health monitoring systems

Operational Areas	Specific Technologies
	Clean/Green technologies • 3D printing or additive manufacturing of materials • Active energy-response building cladding or window technology, including electrochromics and thermochromics • Aerogel insulation • AI tools to monitor impact of infrastructure development to economic cost and well-being of communities • Automatic small-freight transportation system using underground spaces and building conduits • Autonomous vehicles • Battery-free wireless communications • Biofuels • Bioluminescent lighting • Building information modelling systems • Carbon conversion, sequestration, storage in building materials • Carbon fiber bodies • Demand-responsive domestic appliances • Energy self-sufficient megabuilding design construction technology • Flying cars • Fuel cells • Fuel efficient and environment-friendly engines • High-strength wood components and fire-resistant wood structures for the construction of low- and high-rise wooden buildings, such as office buildings • Household waste collection/transportation/categorization system for recycling or energy-recovery • Hybrid electric vehicles • Hyperloop transport • Hypersonic airplanes • Indoor and outdoor operable unmanned vehicle technology • Internet of Things, Internet of Everything • Maglev trains • Micro-hydro system using rainwater in high-rise buildings • Modularization-based LEGO-type one-day housing construction technology • Nano-energy generator • Nanotech improved LED lightbulbs • Natural bioremediation and phytoremediation in and around buildings • Photovoltaic cell • Quantum dot vision windows • Rainwater harvesting
ICT	**Digital Ecosystems** • Quantum Computing • Digital Transformation • Digital Transformed Entity • Digital Twin • User-friendly interfaces of the enhanced ICT ◦ To explore new ways to visualizing how digital information flow • Converting manual steps to digital form • Skills Needed in Developing the Digital Ecosystem ◦ Artificial Intelligence (cross-disciplinary, all levels) ◦ Decision and control scientists and engineers ◦ Computer Scientists ◦ Data Scientists ◦ Information Technologists ◦ Information Systems Managers ◦ Electronics Engineers

Operational Areas	Specific Technologies
	◦ Socio-economic scientists ◦ Programmers ◦ Telecommunications Engineers ◦ Security Specialists ◦ Information Theory Specialists ◦ Digital Networks Specialists ◦ Specific Digital Ecosystems Developers ◦ Artificial Neural Networks and Machine Intelligence Specialists ◦ Software Engineers ◦ Applications-Specific Integrated Circuits (ASIC) Designers ◦ Optoelectronics Scientists and Engineers ◦ Technicians for all the above
Science Education and Talent Retention	**ICT** • Management Information Systems (MIS) • Wireless Communication Technology • Fiber-optic Communication • Information Technology • Simulation Technologies **Internet of Things** **Digital teaching platform (DTP):** e.g. Learning Management System **Immersive Authentic Simulations:** multiuser virtual environments and augmented reality e.g. flight simulators to train pilots **Next generation digital learning environment (NGDLE:** to suit preferred individual and institutional learning environments **ITU-D Study Groups 2019 last mile connectivity measures** • wired systems e.g. optical fiber for high information capacity • traditional wired local area networks e.g. copper coaxial cables to support higher transmission bandwidth and improved modulation • cable TV systems: bi-directional communication, limited user capacity • optical fibre: high capacity, high performance, low error rates **WiFi technology:** hot spots and LANs installed at points of community activities **High Altitude platform systems (HAPS) and unmanned aerial vehicles (UAVs)** e.g. drones as mobile base stations to provide connectivity **Software-defined networking (SDN)** as tool to enable a programmatically efficient network e.g. address challenges in the production, distribution, and use of digital instructional materials
Blue Economy	**Blue Energy** • Blue bioenergy through algal biofuel production • Algal photobioreactors • Algal photovoltaics • Microbial Fuel cell • Blue Biojet Fuel from Hydrothermal liquefaction Process • Integrated bio-refinery in palm oil mill • Ocean thermal energy conversion (OTEC) • Underwater power grid technology and subsea power systems. • Smart energy monitoring and network • Fuel cell • Biomimicry inspired wave and tidal energy • Tidal InStream Energy Conversion (TISEC) **Blue Food and Medicine** • Blue biotechnology for pharmaceutical, cosmetic, food, feeds, and beverages. • IMTA Precision aquaculture (monitoring using wireless mutli-sensors; robotics, mechanized • AI and other STI to improve monitoring and management of fisheries **Blue Transportation and Industries** • Advanced Material Research and Development • Blue nano-materials • Smart Shipping • and e-Boats • Wave disc engines • Ultra capacitor vehicles and watercrafts • Carbon dioxide to carbon nanotubes conversion • Carbon storage in building material • Bioremediation & phytoremediation for hazardous wastes • Smart water monitoring

Operational Areas	Specific Technologies
	• Aerogel insulation technology • Electric and hybrid vehicles and watercrafts • Autonomous vehicles • Carbon dioxide collector for vehicles **Digital Blue Ecosystems** • Advance Material Research and Development • Blue nano-materials • Smart Shipping and e-Boats • Wave disc engines • Ultra capacitor vehicles and watercrafts • Carbon dioxide to carbon nanotubes conversion • Carbon storage in building material • Bioremediation & phytoremediation for hazardous wastes • Smart water monitoring • Aerogel insulation technology • Electric and hybrid vehicles and watercrafts • Autonomous vehicles • Carbon dioxide collector for vehicles **Blue Home Technologies** • Bioluminescent household and street lighting through biomimicry • Rainwater harvesting • Membrane technology for water treatment filtration • Integrated co-processing technology for domestic wastes • Micro-hydro systems using rainwater in high rise building • Solar grey water disinfection • Nanotech improved LED lightbulbs • Bioplastics (Plastic from crops) • Rainwater harvesting
	Blue Education and Tourism • Promoting blue ecosystem conservation via Internet of Things • Carbon Neutral Resorts • S&T incubator and marine technology hub • Geo-tagging for migratory species which can be used for navigation avoidance and biodiversity ecotourism
Business and Trade	**Additive Manufacturing** **High speed, high-capacity computing** • Trade and business information infrastructure at the internal and external • Artificial Intelligence • Big Data • Data science • Automation **High-Throughput, large scale, systematic automated chemometric methods** • Detection • Identification • Quantification • Monitoring **Analytical Methods for biologicals, gene products, substrates and cell activities** • Assessment for the introduction of exotic species • Assessment for the introduction of GMOs and their products • Biosecurity- detect entry of biological warfare materials • Biosafety- detect entry of infected food products **Emerging technologies for product inspection during transport (Rouhi, 1995)** • Computed tomography: using x-ray to reconstruct cross sectional image of an object • X-ray scanners • Nuclear Quadrupole Resonance: detection of quadrupole moments of elements used in explosives • Neutron Analysis: Materials bathed with neutrons will emit gamma-rays whose energy and intensity are characteristic of component elements like nitrogen. • Vapor detection methods: characteristic vapor emitted by material **Recycling Technology materials derived from production and obsolete products**

LIST OF TECHNOLOGIES PER OPERATIONAL AREA

Operational Areas	Specific Technologies
Governance	• **Internet** • **National ID system** • **Election computerization** ◦ national voter registration systems ◦ use of telephones and online portals • **National defense technologies** ◦ Secure and reliable communications systems ◦ Locally-produced combat rations ◦ Survival technology for injuries and infections ◦ Technology to identify casualties ◦ Cyber, spaced-based, unmanned, autonomous, and other complex military systems, e.g., hypersonic weapons (Stone 2020) and laser weapons (Lockheed Martin 2020) ◦ Unmanned aerial systems ◦ Precision munitions ◦ Robust and secure military transport systems- land, air, and water ◦ Electro-optic/infrared countermeasures (Lockheed Martin 2019) • **National statistics system** • **ICT-based information and documentation services** • **Forensic services** • **Customs enforcement** • **Humanitarian emergency-response technologies** • **Geographic information systems** • **Culture heritage preservation technologies**
Space Exploration	• **Upstream activities: design, assembly, integration and testing of satellites, other spacecraft and their payloads, systems, subsystems, and components** ◦ includes space infrastructure: rockets, spaceports/launch sites • **Downstream activities: use of space systems to develop and deliver products and services for scientific, experimental and commercial applications** ◦ e.g. telecommunications, navigation, surveillance, Earth observation, etc. • **Geospatial information management** • **Precision agriculture systems that make use of satellite data** • **Satellite observations and maps in aiding farm productivity and monitoring precipitation, waterways, aquifers, etc.** • **Use of satellite instruments to assist in climate change mitigation and disaster response** • **Remote sensing** • **Data science** • **Machine learning or AI** • **Robust ground calibration networks (e.g., spectrometers, LIDAR, flux towers, etc.)** • **Use of hyperspectral satellites to monitor essential biodiversity variables of coastal ecosystems**

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