SECTION 4

Facets of Philippine Science, Techonology, 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).

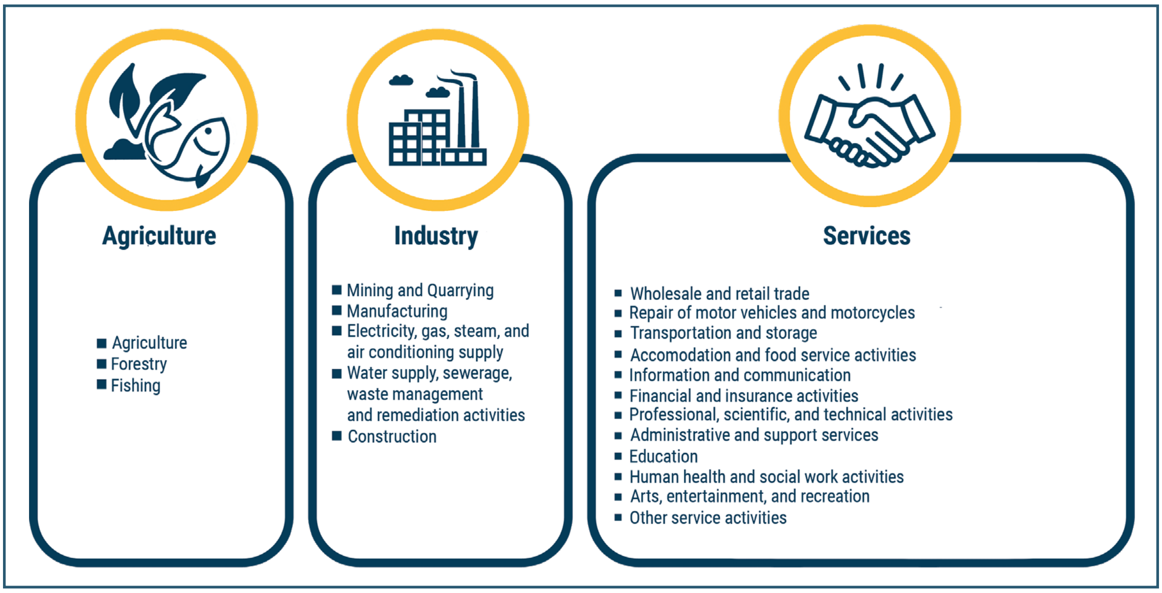


Figure 4.3_1. The Sectors and Sub-sectors of the Philippine Economy
Source: PSA (2020a)

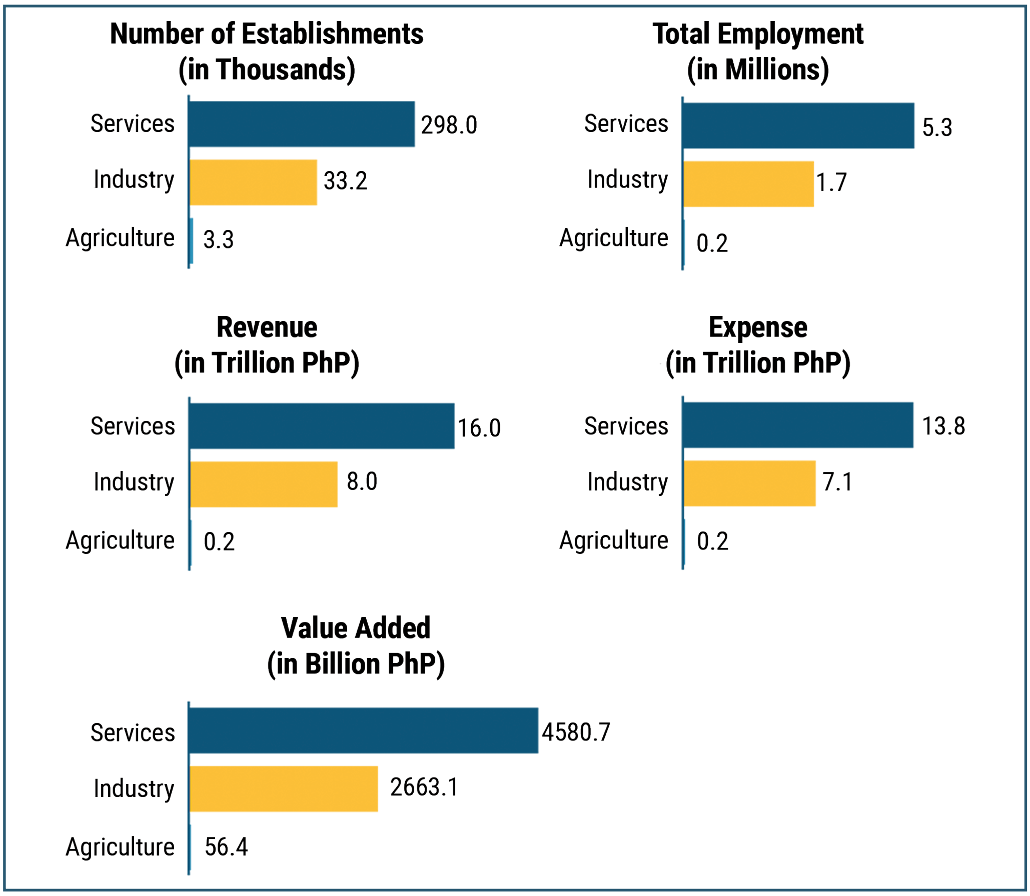


Figure 4.3_2. Selected Statistics on Major Economic Sectors, 2018 CPBI
Source: PSA (2020a)

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_3. 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_4. 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 & 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 percent 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 & Development for Technology (ERDT) Program. The ERDT has improved COE's PhD production to 12.8 $\pm$ 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 $\pm$ 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. Unfortunately, the PhD Geology program in CS is being scrapped.

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 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).

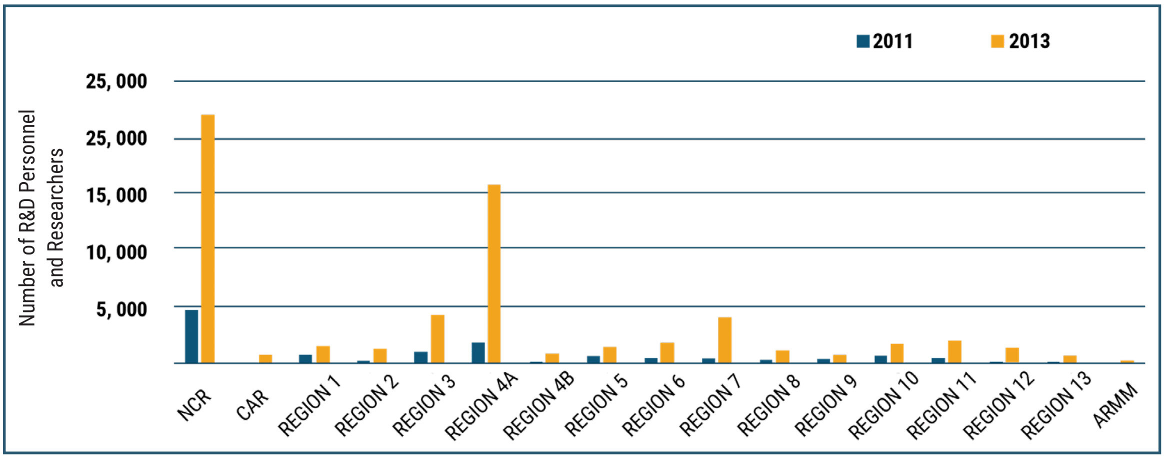


Figure 4.5_1. Number of R&D Personnel and Researchers in the Regions 2011 and 2013
Source: DOST (2015)

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 nutritionsensitive 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.

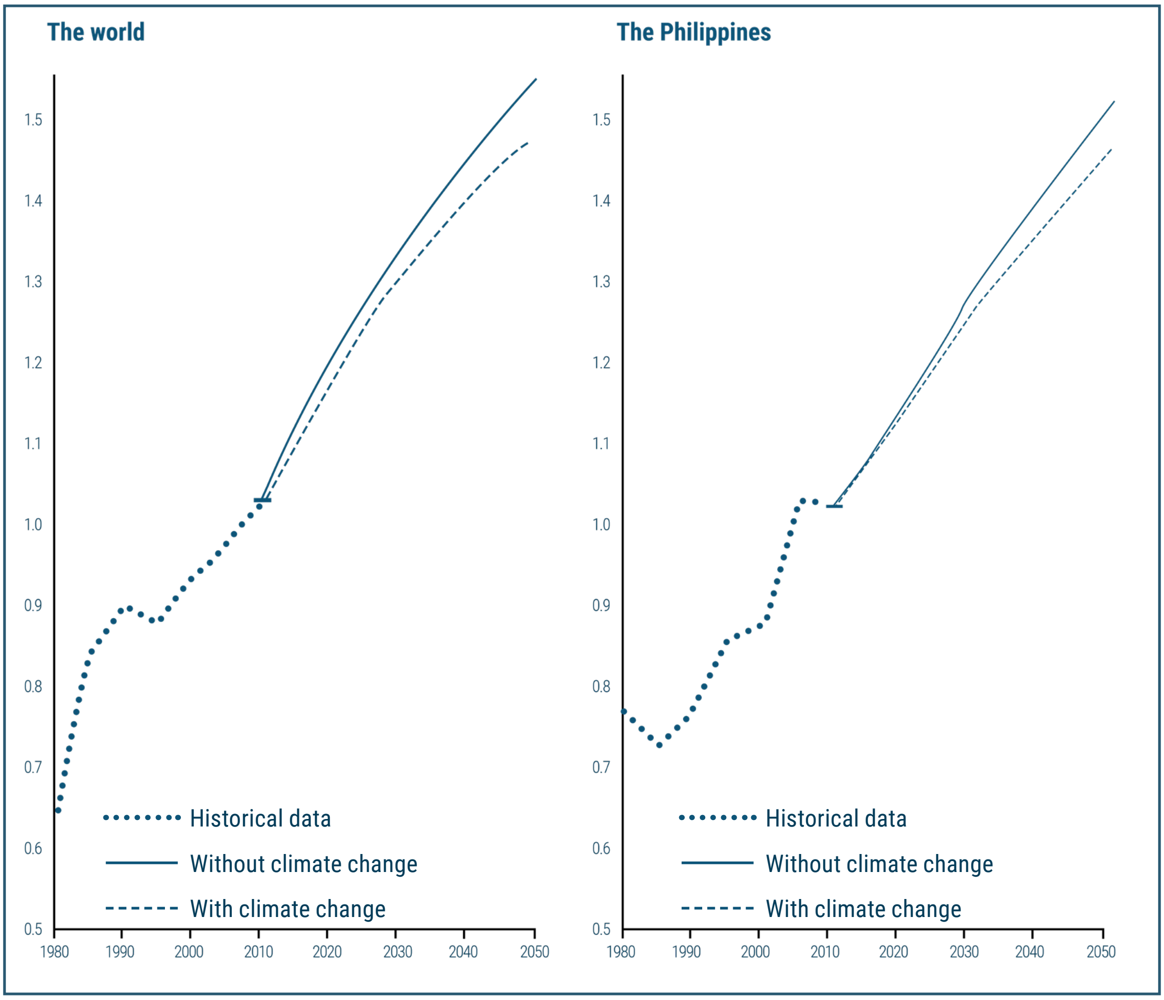


Figure 4.6_1. Historical and Average Projected Agricultural Crop Yields, with and without Climate Change, 1970–2050

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 2030	The World 2050	Philippines 2030	Philippines 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).

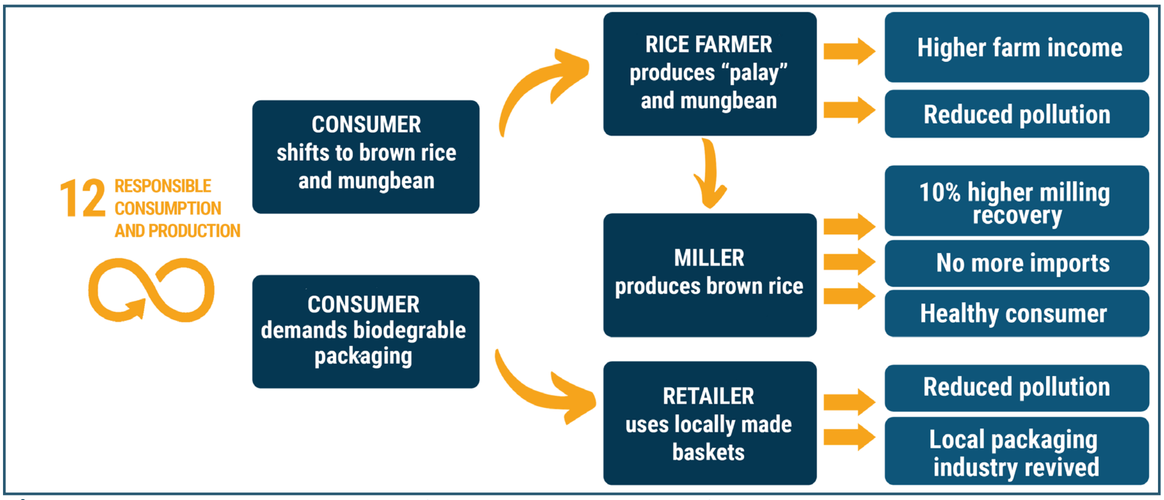


Figure 4.6_2. Consequences of Consumer Choice of Food and Packaging.

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	Transcdisciplinal
Ecosystem/Landscape	• Organic and traditional farming • Controlled environment frarming (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.)

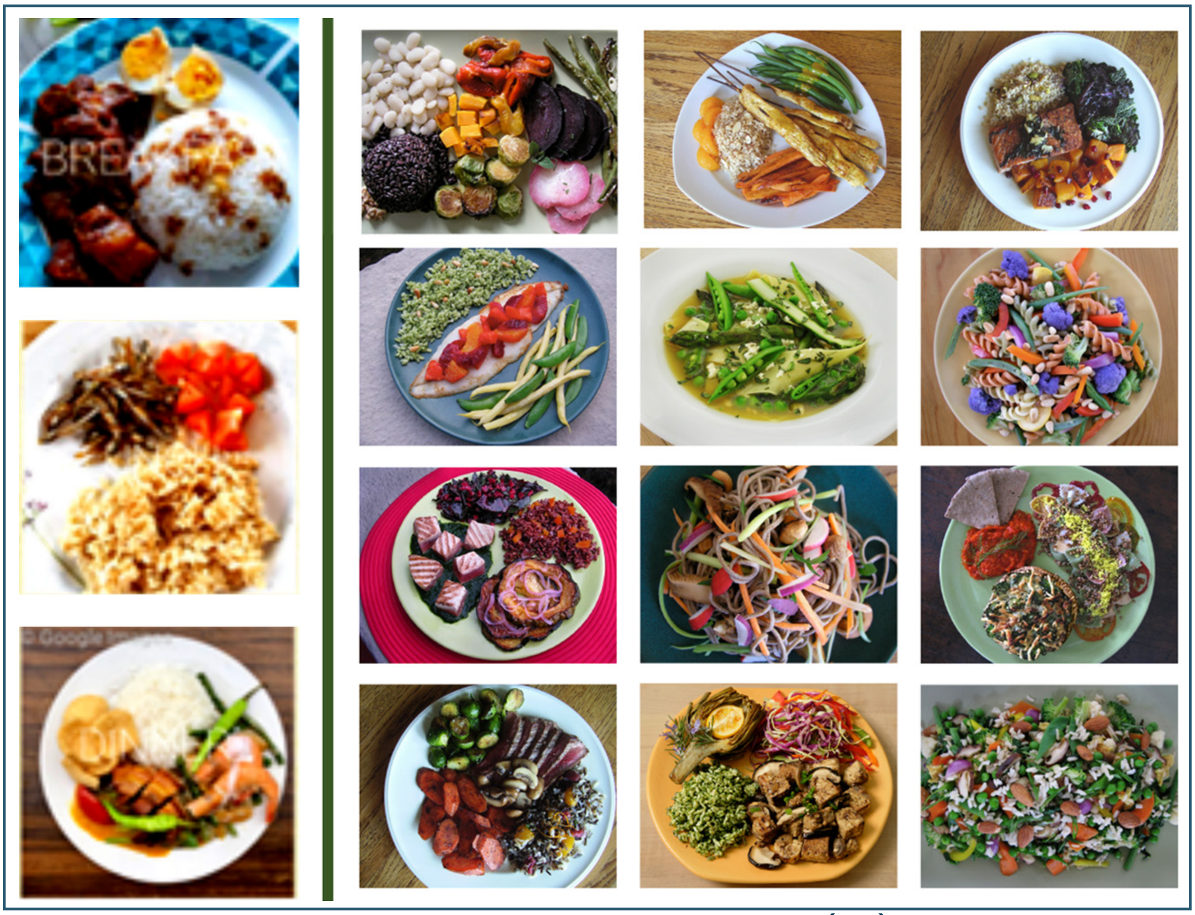


Figure 4.6_4. Comparison Between the Typical Filipino Diet (left) and Different Versions of the Planetary Health Diet (right)
Source: EAT (2019)

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.

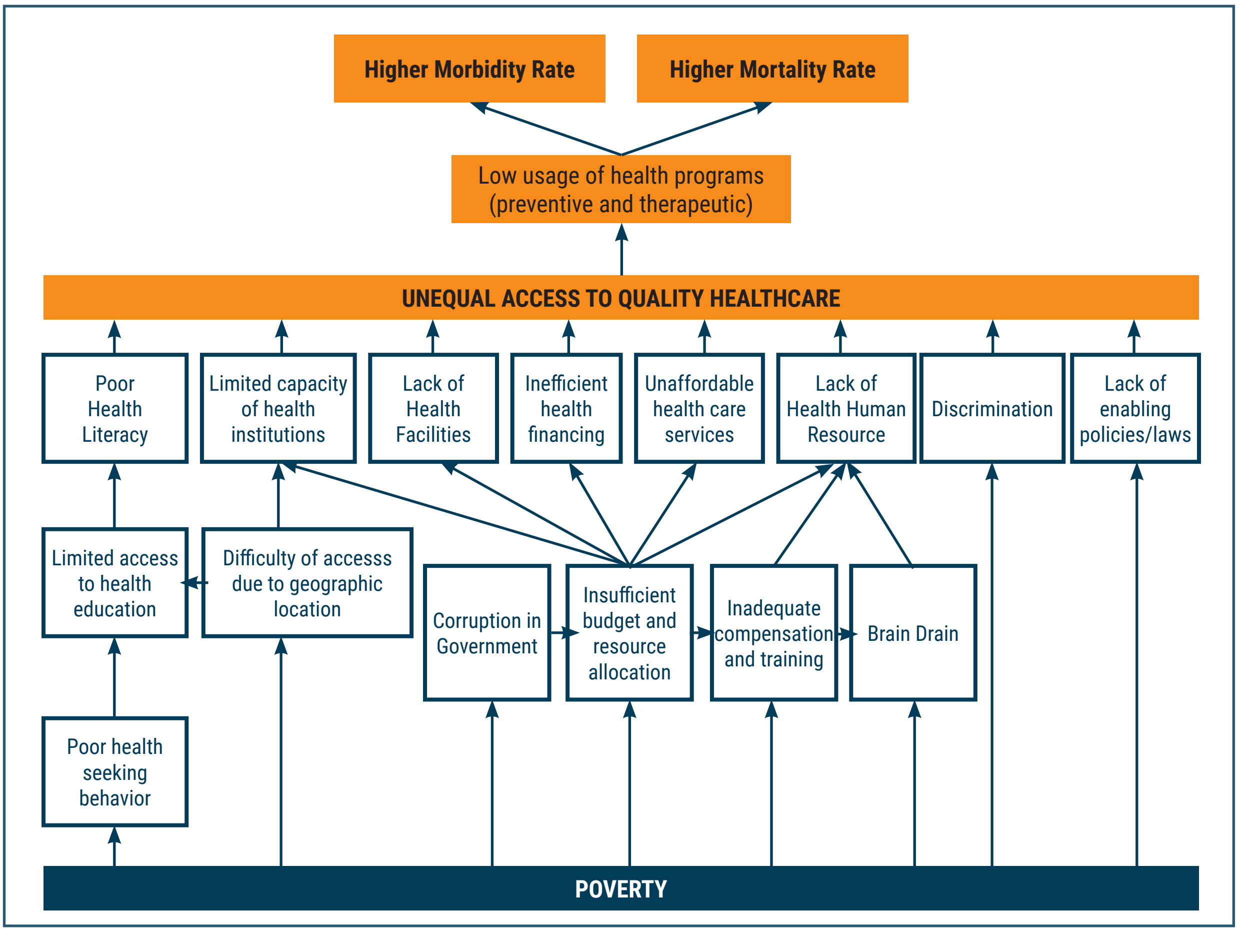


Figure 4.7_1. Health Group Problem Tree Analysis Output from the STI Foresight SWOT and TOWS Workshop on 22-23 October 2020.

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

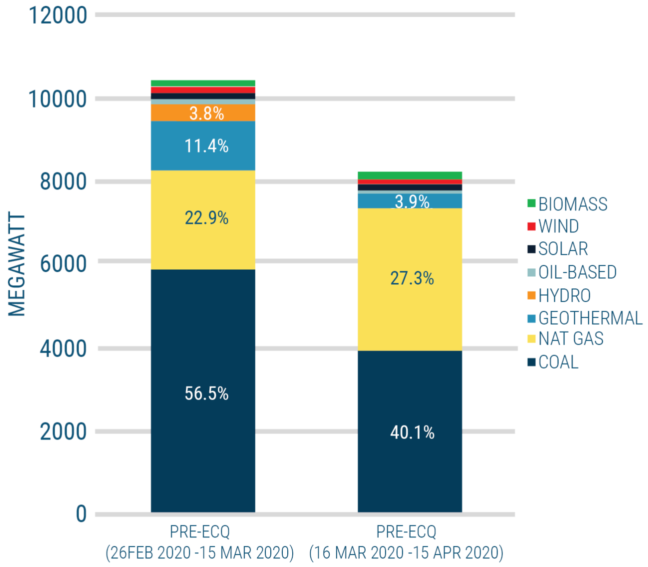
(h) Constant 2005 USD prices and exchange rate

(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		Fuel Type	ECQ	
Hourly Average, MW	%Share of Total		%Share of Total	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.

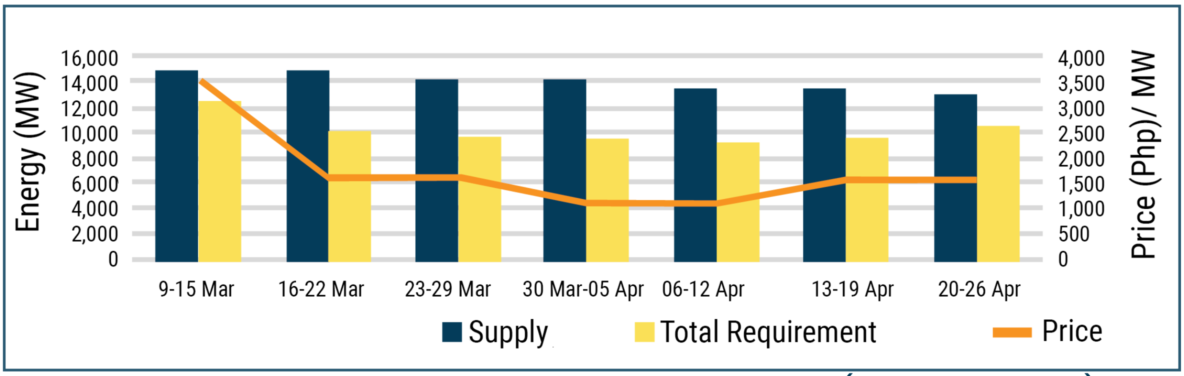


Figure 4.8_2. Average Supply and Total System Requirement (Energy + Reserve)
Source: WESM IEMOP (2020)

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).

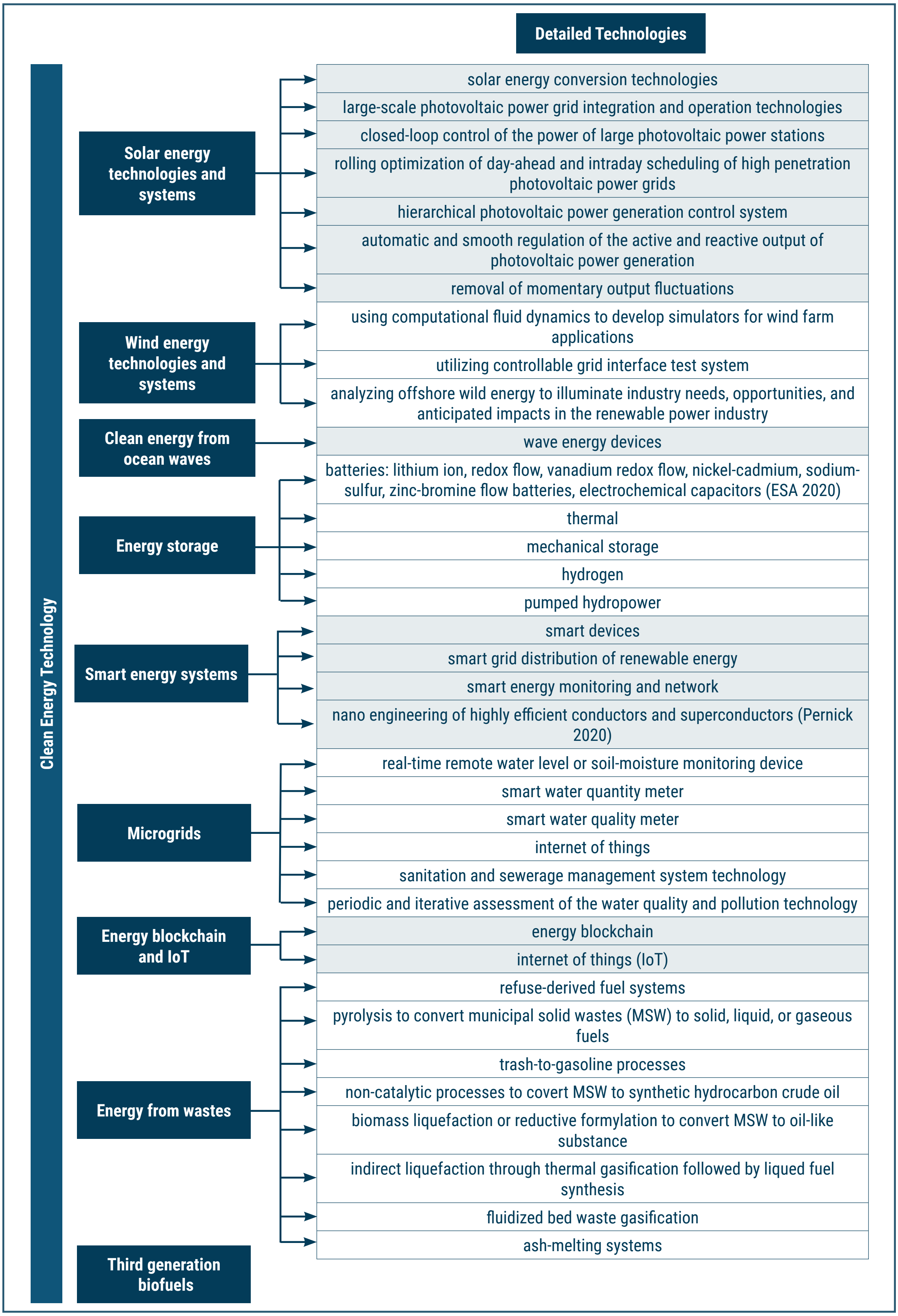


Figure 4.8_3. Clean Energy Technology
Sources: Uriarte (2008, 2010, 2017), Liu (2015), Clean Energy BC (2015), Lund et al. (2017), Ellsmoor (2018), WETO (2018)

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).

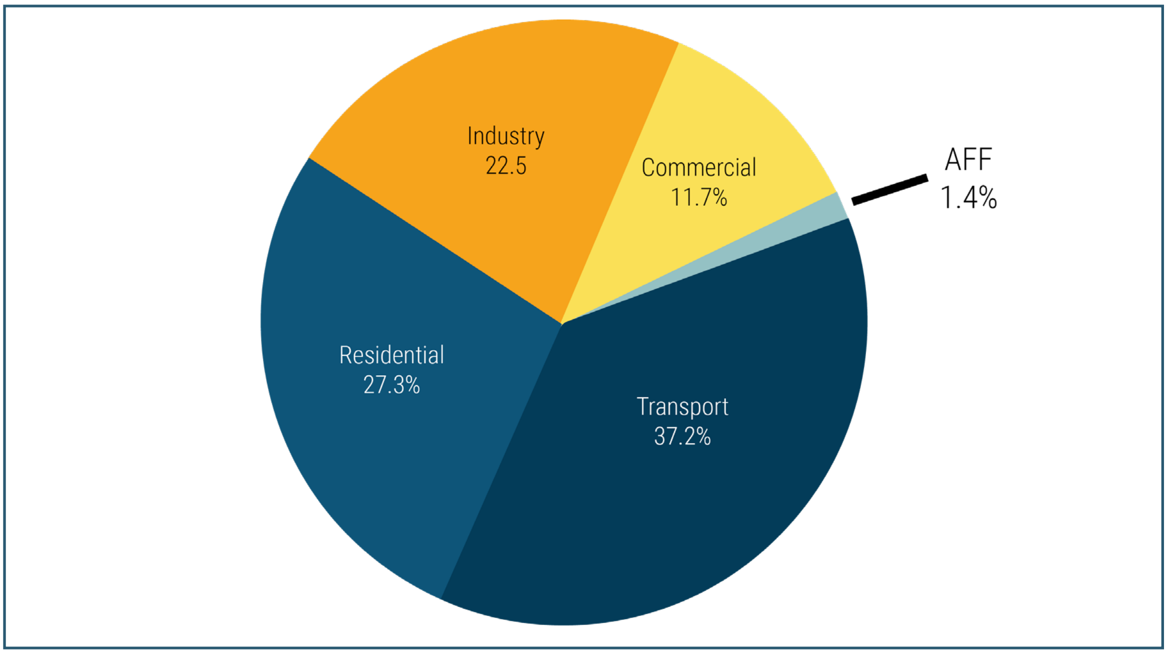


Figure 4.8_4. Total Final Energy Consumption by Sector (2016), Percentage Shares
Source: DOE (2019)

Petroleum products garnered the bulk of the country's total final energy consumption, with a 49.3% share (Figure 4.8_5).

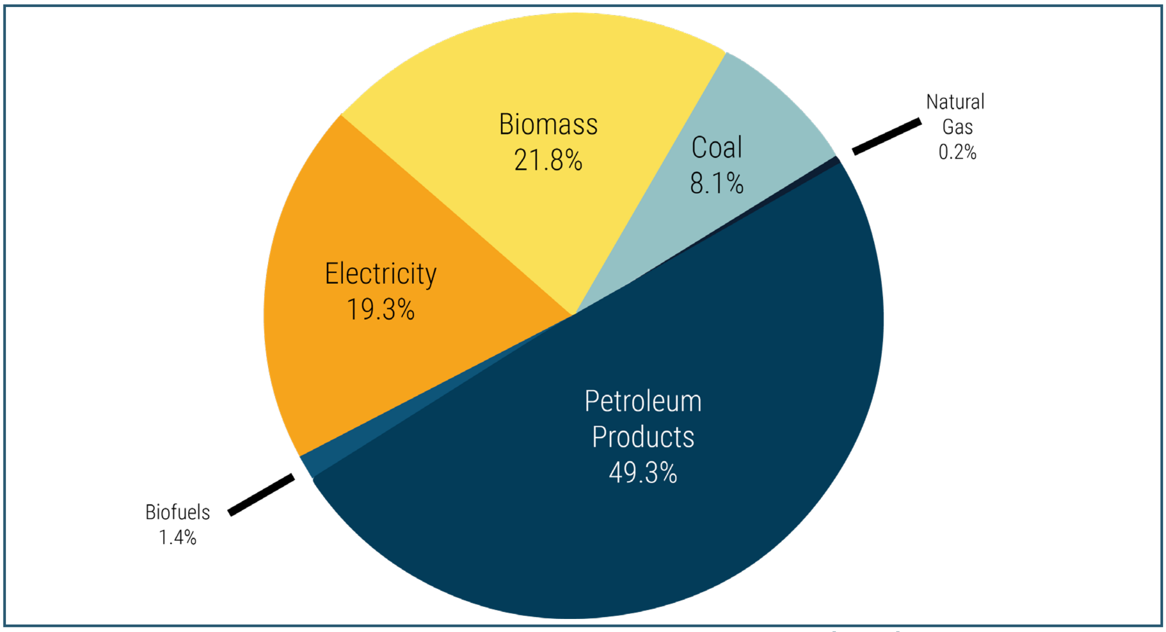


Figure 4.8_5. Total Final Energy Consumption by Fuel Shares (2016)
Source: DOE (2019)

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 percent, respectively (Figure 4.8_6).

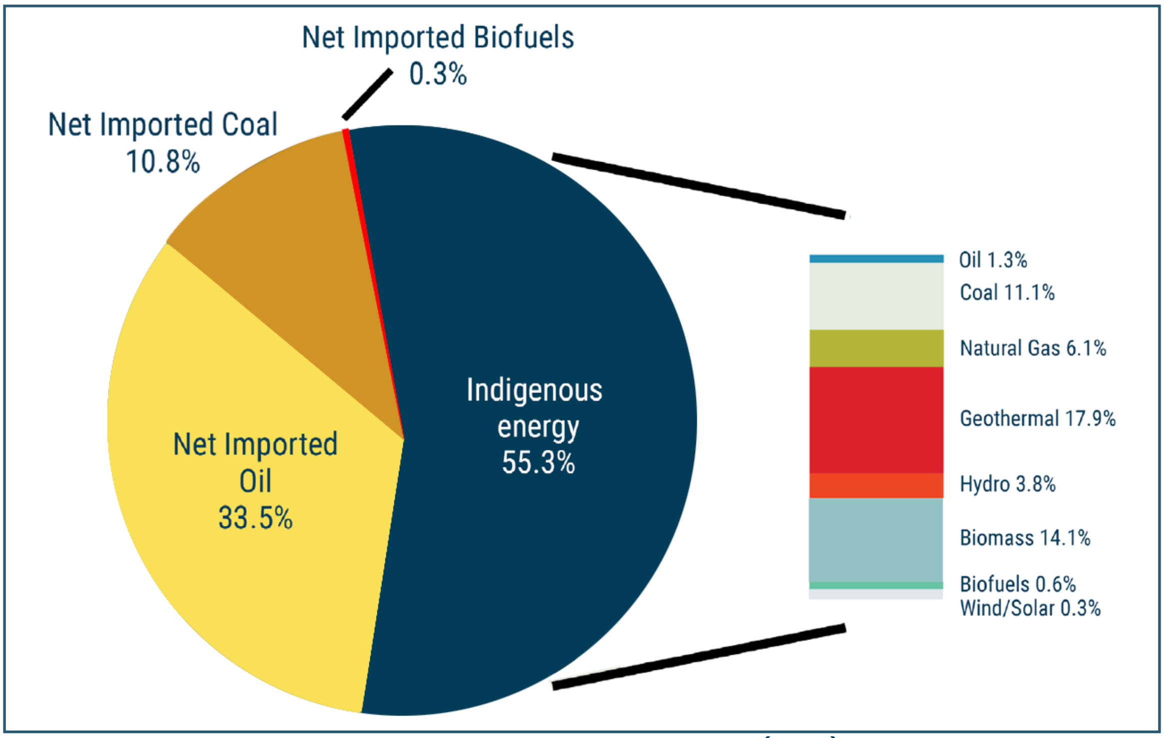


Figure 4.8_6. Total Final Energy Consumption by Sector (2016), Percentage Shares
Source: DOE (2019)

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.

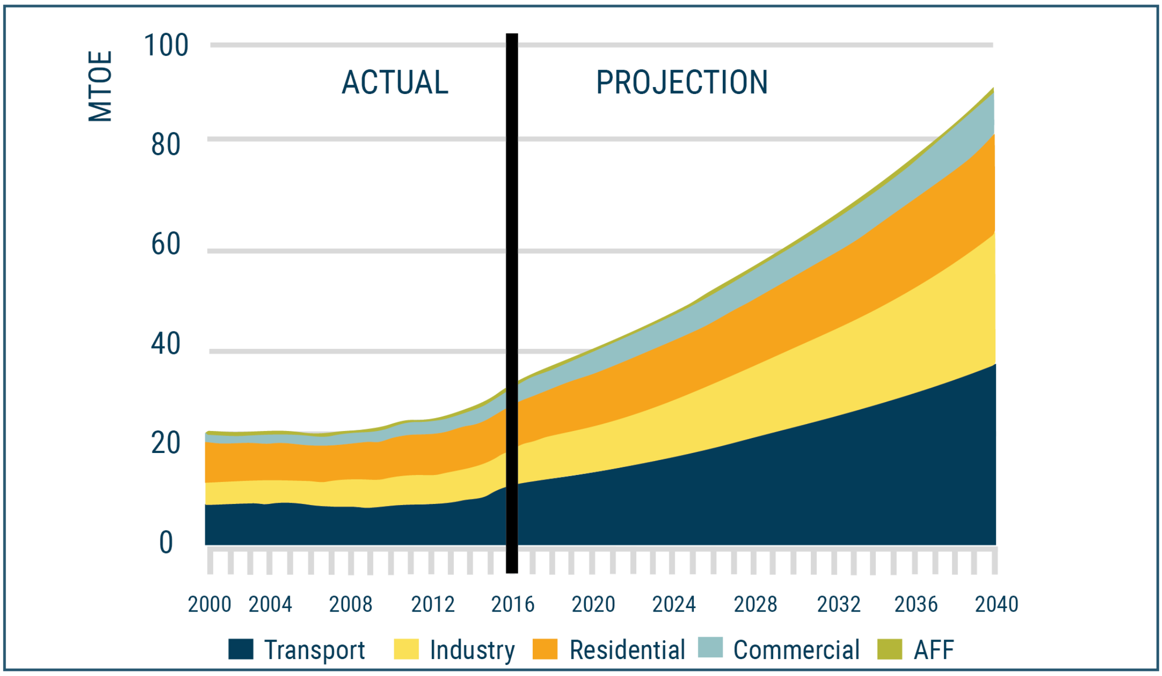


Figure 4.8_7. Total Final Energy Consumption, by Sector (2000–2040)
Source: DOE (2019)
Note: Energy consumption expressed in terms of million tons of oil equivalent (MTOE)

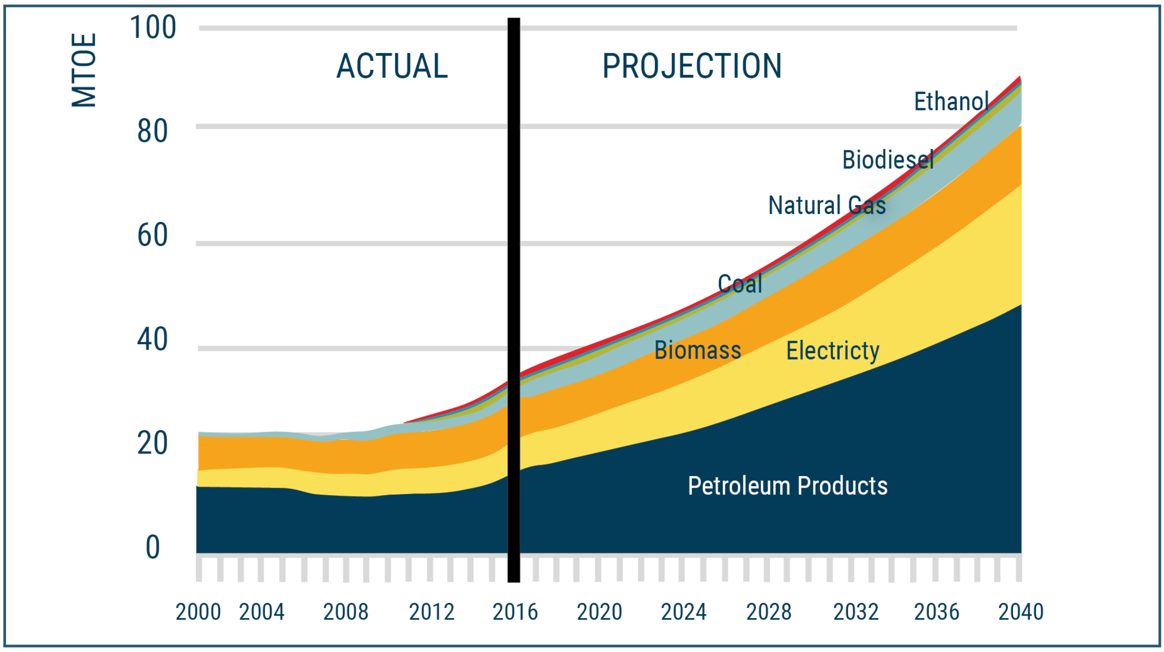


Figure 4.8_8. Total Final Energy Consumption, by Fuel (2000–2040)
Source: DOE (2019)
Note: Energy consumption expressed in terms of million tons of oil equivalent (MTOE)

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 percent, 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.

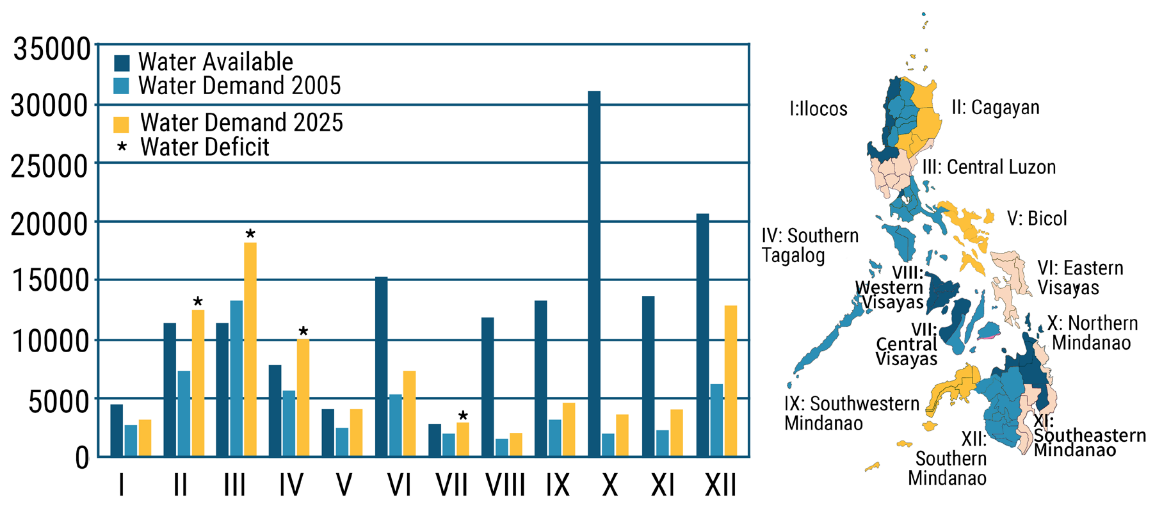


Figure 4.9_1. Projected Regional Supply and Demand Situation in Thousand cu m (2005-2025)
Source: JICA and NWRB (1998)

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).

Clean Water Technology

	Detailed Technologies
Rainwater Harvesting	Small-scale water cisterns to collect 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).

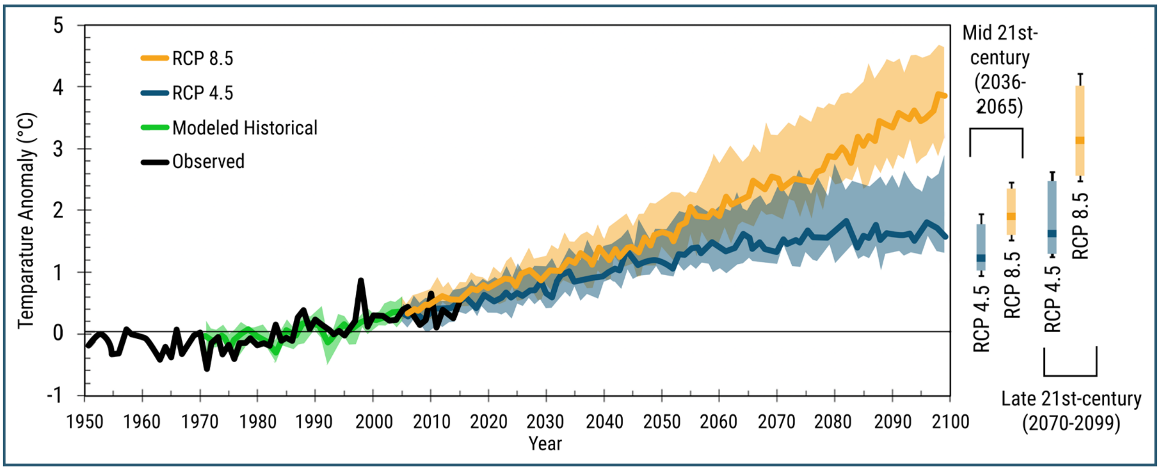


Figure 4.10_1 Projected Air Temperatures for the Philippines with Climate Change
Source: DOST-PAGASA (2018)
Note: RCP - Representative Concentration Pathway

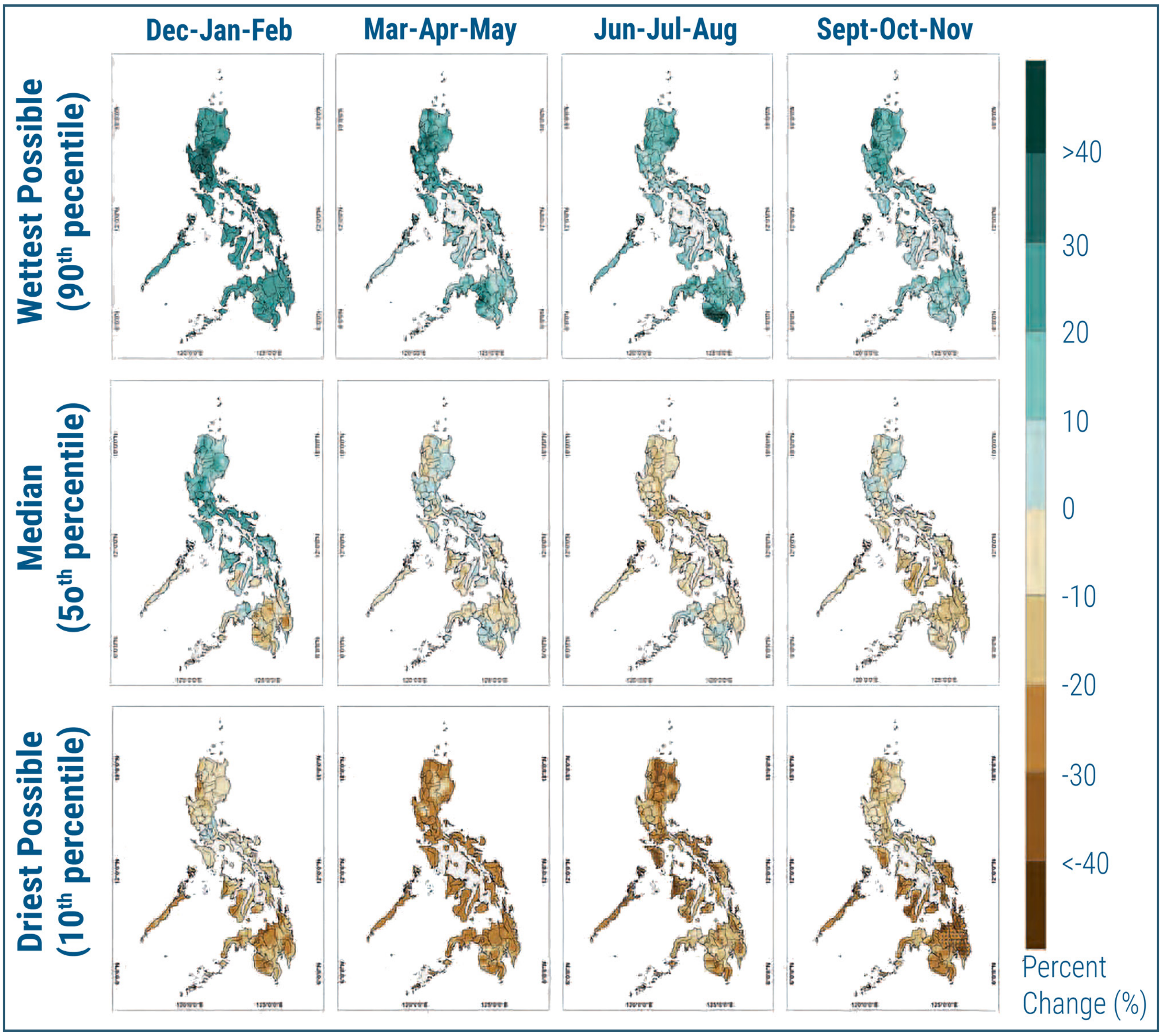


Figure 4.10_2. Projected Seasonal Change in Rainfall in the Philippines for the Mid-21st Century (2036-2065) Relative to the Baseline Period of 1971-2000.
Source: DOST-PAGASA (2018)

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.

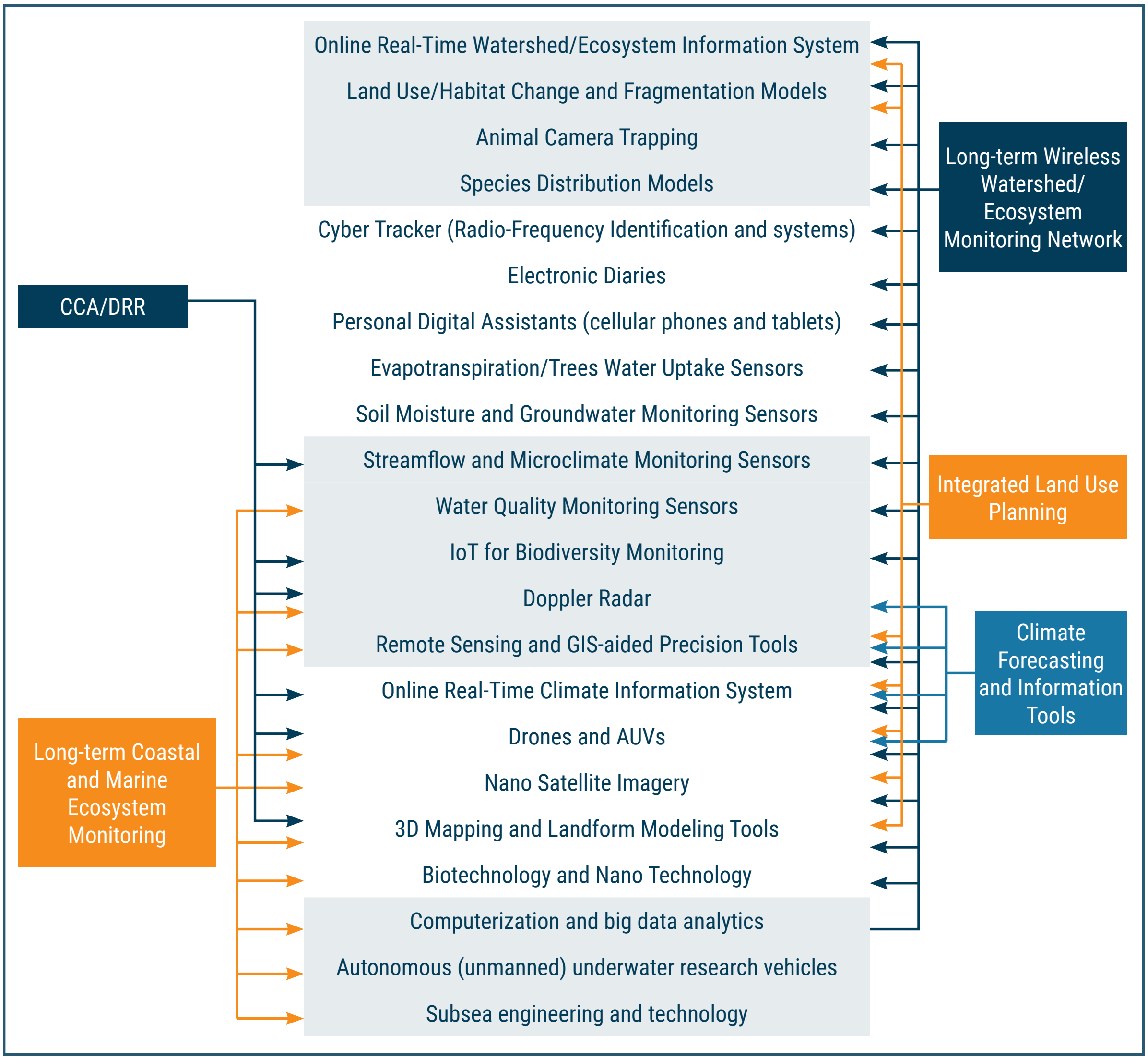


Figure 4.10_3. Summary of Science, Technology and Innovation for Sustainable Use, Climate Change Action and Disaster Risk Reduction for Terrestrial, and Coastal and Marine Ecosystems.
Note: CCA/DRR - Climate Change Action and Disaster Risk Reduction

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).

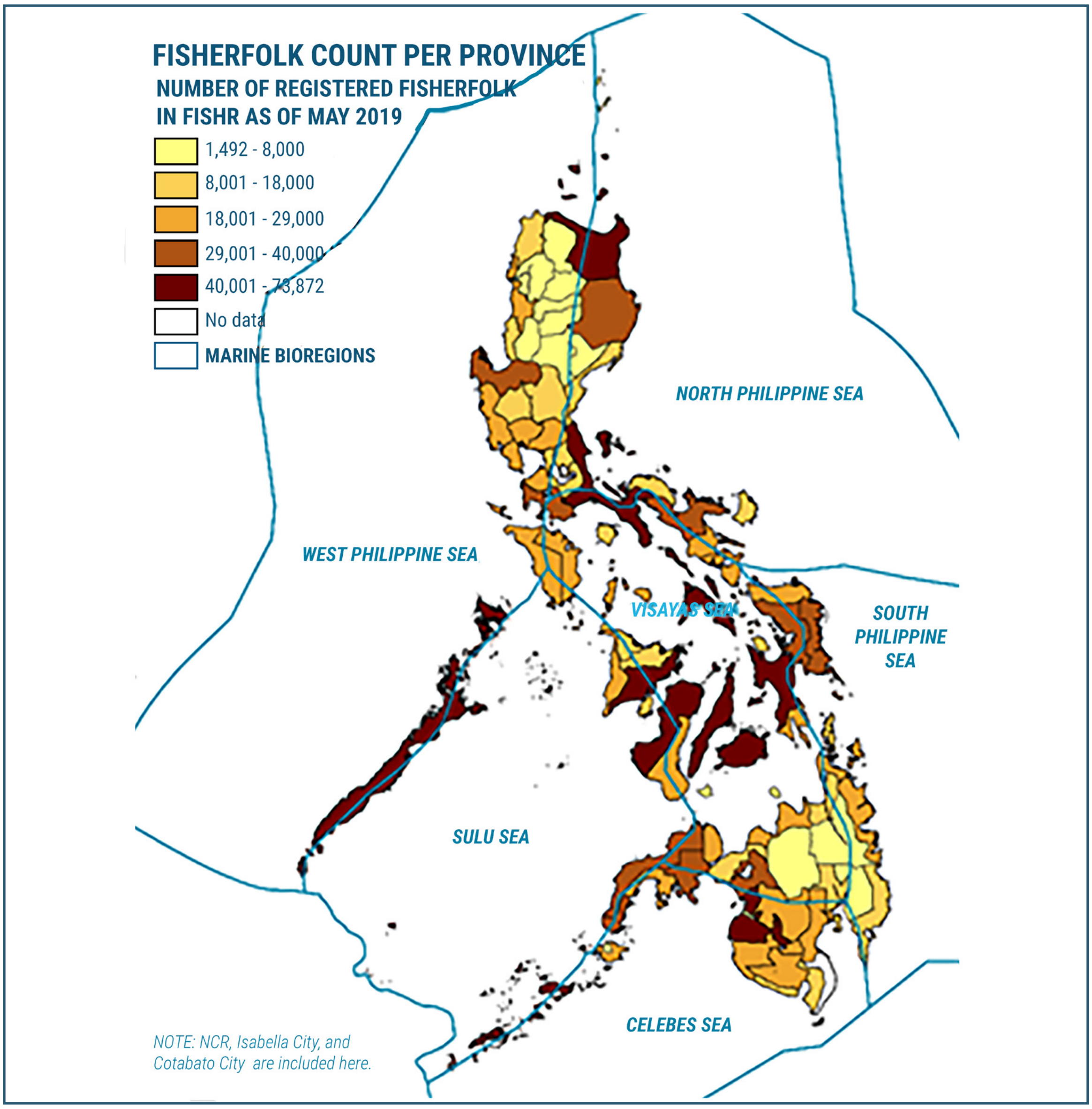


Figure 4.10_4. Fisherfolk Count per sq km of Municipal Waters
Source: BFAR (2019)

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 percent 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.

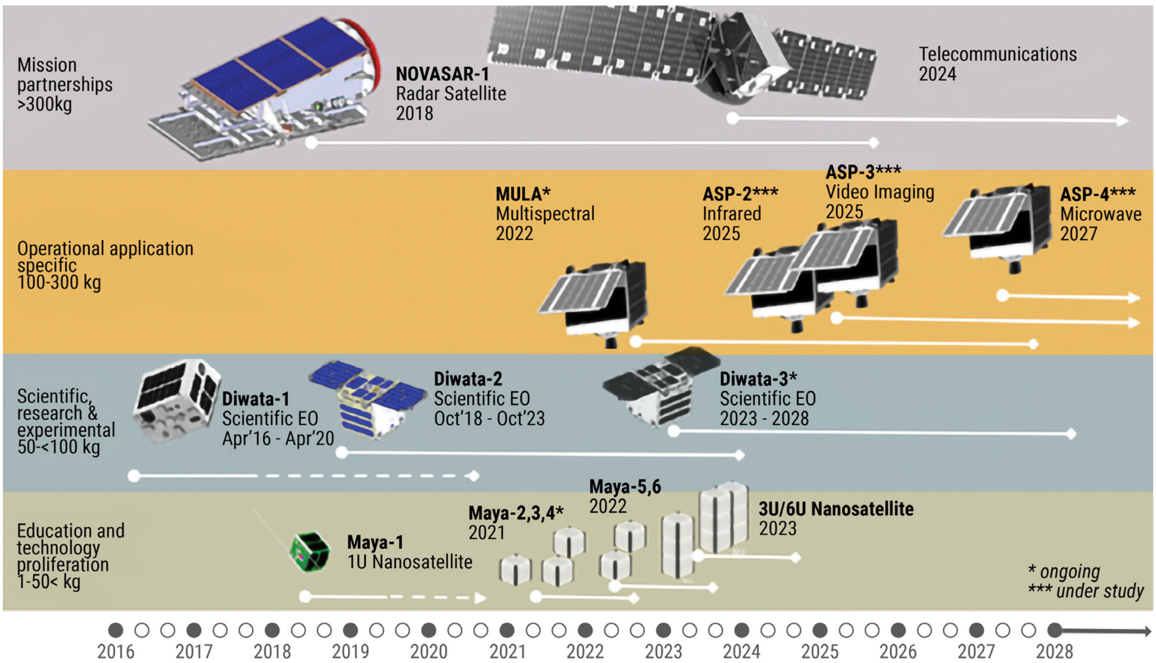


Figure 4.12_1. Near- to Medium-Term Capability Roadmap in Satellites and Upstream Space Development

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.