SECTION 6

A Roadmap to the Future

SECTION 6.1
DELPHI SURVEYS, TECHNOLOGY CLUSTERS, AND FORESIGHTING

DELPHI Survey Results

After two rounds of Delphi surveys (see Section 1.1), respondents from across the National Academy of Science and Technology, Philippines (NAST PHL) and experts managed to reach a consensus on the ten key points (Table 6.1_1).

Seventy-four percent of 206 respondents expected changes in the aspirations outlined in AmBisyon Natin 2040 due to COVID-19. Based on rankings, respondents named the following as the topmost priorities:

(1) eliminate poverty and hunger
(2) ensure improved wellbeing of Filipinos (well-being here is the state of being happy, comfortable, and healthy)
(3) foster innovation

The above-mentioned priorities were also reflected in the top trends that respondents considered in the foresight. Expectedly, the topmost answer was growing poverty and hunger. These were followed by climate change and deepening environment risks and growing inequality. Respondents also agreed that the most significant disruption as Filipinos journey to 2050 would be the recovery from globally disruptive events such as pandemics and armed conflicts. Acute climate events came in second, followed by the sustainability of science, technology, and innovation (STI) interventions.

In terms of adequacy of the current STI foresight, 69% of 243 respondents did not name additional areas for consideration. Marine science was identified as the field of current strength of STI in the Philippines. Excellence was also observed in agriculture with rice science and technology and major export crops. Respondents also evaluated the importance and feasibility of the Philippines as the leading global or regional centers in the following areas by 2050:

(1) regional center of agricultural biotechnology research, development, and innovation
(2) leading global center of excellence in marine science
(3) leading global center in disaster risk management

When asked about public and private institutional and organizational changes needed to enhance the role of STI in the development and daily lives of Filipinos, there was consensus that changes are needed to improve the quality of Science, Technology, Engineering, and Mathematics (STEM) instruction in K-12. This was followed by the improvement in the quality of instruction at the undergraduate level in Philippine Higher Education Institutions (HEIs) while science literacy program development and institutionalization were third. Aside from changes in public and private organizations and institutions, respondents answered questions on the improvement of quality and quantity of talent development and retention in STI. The following mechanisms were ranked based on importance:

(1) create attractive, regular, and stable employment opportunities for highly trained STI workers in the public and private sector
(2) improve the ecosystem for the conduct of research and development (R&D) in the Philippines
(3) expand incentives for the Philippines to be attractive to knowledge workers (local and foreign) including formulation of appropriate immigration policies and review of relevant existing laws

The respondents also believed that STI could be harnessed to assert our sovereignty and identity as a maritime nation. Almost 70% of 243 respondents said all of the following should be done concerning the Philippine seas:

- publish and popularize and widely disseminate a scientifically designed map showing the maritime territorial limits of the Philippines as confirmed by international bodies like UNCLOS and the Tribunal
- expand surveillance capability of the Philippine Coast Guard to effectively monitor our territorial limits by using well-designed watercrafts and sensors attached to autonomous unmanned water vehicles
- initiate wider exploration of the Philippine territorial waters for valuable and strategic natural resources
- support R&D initiatives to work on an inventory of biological resources in Philippine territorial waters
- collaborate with other countries in Asia for an integrated marine resource management program

The last part of the Delphi survey dealt with public investments and interventions and STIs that could stimulate and shape technologies to reduce poverty or conditions associated with poverty. Respondents had a consensus that public investments should be allotted to ensuring equitable access to nutritious and affordable food. This was followed by the following: improving access to clean domestic water supply and sanitation in rural areas and urban slums and designing and implementing resilient and efficient supply chains.

Table 6.1_1. Top Three Answers in the Delphi Survey Questions

Delphi Survey Questions	Top Three Answers
1. Do you expect any changes in the expressed aspirations in the light of the COVID-19 pandemic (including the post-pandemic period 10 years hence) until the mid-century year 2050?	(1) eliminate poverty and hunger (2) ensure improved wellbeing of Filipinos (wellbeing here is the state of being happy, comfortable, and healthy) (3) foster innovation
2. What socio-cultural, technological, economic, environmental, and political megatrends, both global and local, should be considered in this foresight exercise?	(1) growing poverty and hunger (2) climate change and deepening environment risks (3) growing inequality
3. What uncertainties, black swans or disruptions do you expect as we journey 2050?	(1) recovery from globally disruptive events such as pandemics and armed conflicts (2) acute climate event came in second (3) sustainability of STI interventions.
4. Are there additional areas that we need to consider for this STI Foresight?	No additional areas for consideration.
5. What do you perceive as the current areas of excellence/strength in STI (including the social sciences) in the Philippines?	(1) marine science (2) rice science and technology (3) major export crops
6. What additional areas of excellence/strength would you want the Philippine STI (including the social sciences) to be leading global or regional centers by 2050?	(1) regional center of agricultural biotechnology research, development, and innovation (2) leading global center of excellence in marine science (3) leading global center in disaster risk management
7. What public and private institutional or organizational changes should take place to enhance the role of STI in development and in the daily lives of the Filipinos? (e.g., Public-Private Partnership in R&D, reorganization of DOST, STEM instruction in K-12, etc.)	(1) improve the quality of STEM instruction in K-12 (2) improve the quality of instruction at the undergraduate level in Philippine HEIs (3) science literacy program development and institutionalization
8. What measures should be taken to improve the quality and quantity of talent development and retention in STI?	(1) create attractive, regular, and stable employment opportunities for highly trained STI workers in the public and private sector (2) improve the ecosystem for the conduct of R&D in the Philippines (3) expand incentives for the Philippines to be attractive to knowledge workers (local and foreign) including formulation of appropriate immigration policies and review of relevant existing laws.
9. How can STI be harnessed to assert our sovereignty and identity as a maritime nation?	All of the following should be done concerning the Philippine seas: publish, popularize and widely disseminate a scientifically designed map showing the maritime territorial limits of the Philippines; expand surveillance capability of the Philippine Coast Guard; initiate wider exploration of the Philippine territorial waters; support R&D; and collaborate with other countries in Asia.
10. What public investments and interventions in STI can stimulate and shape technology to reduce poverty or the conditions associated with poverty by providing opportunities for those who are living at the edge of subsistence?	(1) ensure equitable access to nutritious and affordable food (2) improve access to clean domestic water supply and sanitation in rural areas and urban slums (3) design and implement resilient and efficient supply chains

SECTION 6.2
THE SCIENCE, TECHNOLOGY, AND INNOVATION ROADMAP

This Science, Technology, and Innovation (STI) Foresight culminates with the STI Roadmap that reiterates cluster goals for the preferred future, science, and technology (S&T) enablers, drivers, and opportunities. The roadmap is a product of numerous National Academy of Science and Technology activities, including technology forecasting (Salvacion 2020), Delphi survey, virtual workshop on the scenario planning, focus group discussions, technology mapping, and iterations with the NAST Foresight Steering Committee.

The framework of the Integrated STI Roadmap consists of four parts (Figure 6.2_1) namely:

- Four innovation phases
- STI Clusters
- Science and technology enablers
- Drivers and opportunities

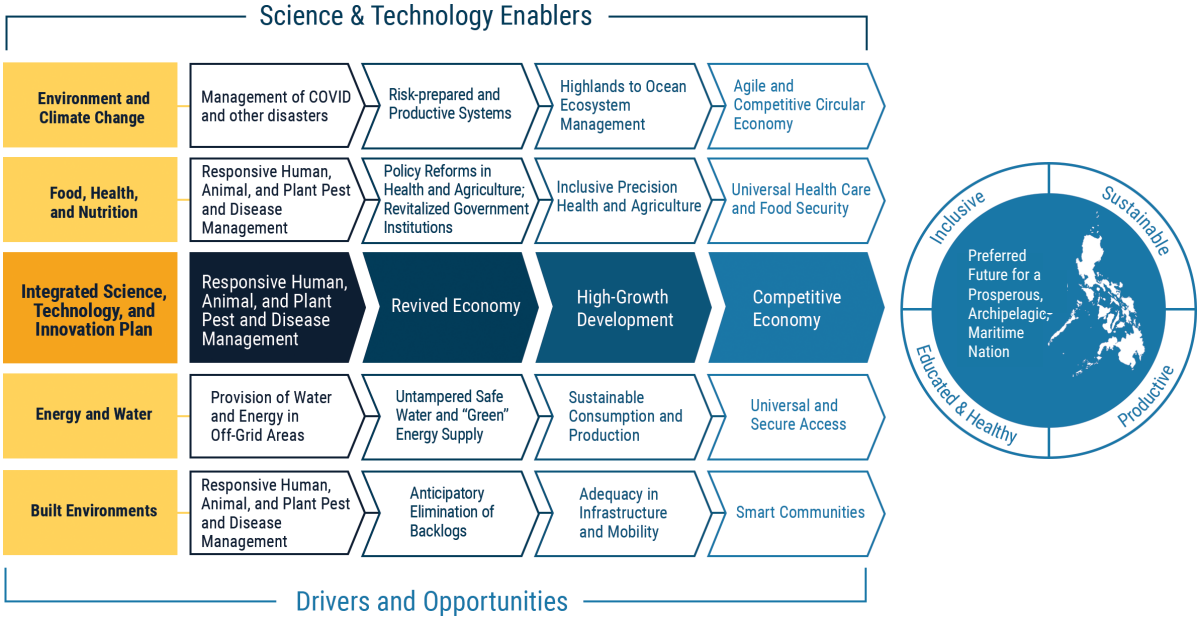

Figure 6.2_1. Integrated STI Roadmap

Innovation Phases

The four innovation phases start with the recovery period through the Responsible Management of Pests and Diseases. As of this writing, the COVID-19 pandemic continues to infect thousands and the African Swine Flu has also infected significant numbers of the swine industry. Thus, the need to harness the know-how from STI to contain the spread of variants of COVID-19 and other diseases that affect not only humans but also the sources of food such as crops, livestock, poultry, and fisheries.

The recovery phase is then followed by the Revival of the Economy where the inertia imposed by the pandemic is replaced by the momentum of activities that will set the stage for the next innovation phase for High Growth Development.

The third phase is characterized by the application of advanced technologies to enhance economic growth and national well-being.

The fourth innovation phase is characterized as a Competitive Economy marked by the entry of a good number of Philippine products and services in the global market.

Due to uncertainties, risks, and shocks, including the black swans, that may occur within the 30-year period of this foresight, no fixed timelines have been indicated for the four innovation phases. The pace of development may differ among the four clusters.

The goal of the STI Roadmap is for the Philippines to eventually become a Prosperous, Archipelagic, Maritime Nation characterized by a society that is inclusive, productive, sustainable, educated, and healthy.

Science, Technology, and Innovation Clusters

As indicated in the earlier parts of this Foresight, the six of the operational areas have been grouped into four clusters based on their close relationships in STI. The four clusters are:

- Environment and Climate Change
- Food, Nutrition, and Health
- Energy and Water
- Built Environments (Shelter, Transportation, and Other Infrastructure)

The integrated futures within and across clusters were derived mainly from the back casting discussions.

Science and Technology Enablers

The S&T enablers include existing technologies and areas that serve as backbones of successful STIs, such as science education, business and trade, blue economy, and governance. These technologies and operational areas provide the tools, and the know-how that will enable the socio-cultural, technological, economic,environmental, and political factors to work harmoniously towards national well-being.

Drivers and Opportunities

Uncertainties, risks, and shocks brought about by natural disasters and human events are both drivers and opportunities for change. The pace of the developments in each innovation phase will be determined by how well Philippine society and its leaders have been able to discern, anticipate, and manage disruption and/or the opportunities brought about by the social, technological, economic, environmental, and political forces that emerge during the period of this Foresight.

Environment, Climate Change, and Space Exploration Cluster

While commonalities could be observed in the maps, goals are unique, and some S&T enablers, drivers, and opportunities are inherent in a particular cluster.

For the Environment and Climate Change cluster (Figure 6.2_2), the initial goal for the recovery period is to effectively manage COVID-19 and other pests and diseases including those that affect food crops, livestock, poultry, and fisheries. This is necessary for the cluster to achieve an agile and competitive circular economy. It is anticipated that the act of balancing between development and protection of the environment/resources will become more challenging as more people compete for survival, livelihood, and economic gains.

Drivers for this cluster include natural disasters like floods, landslides, and tsunamis from seismic events or typhoons with heavy precipitation and strong winds. Other land- and marine-based disasters such as outbreak of diseases in humans, plants, and animals that may be influenced by climate change related phenomena like prolonged El Niño and La Niña, rise in land and sea surface temperature, sea level rise, and ocean acidification. Land and marine pollution are generally anthropogenic and inter-related whose negative impacts are exacerbated by climate change.

At the local or national level, opportunities include industrialization with accompanying infrastructure and technological development and utilization in the areas of agriculture, aquaculture, and fisheries. Long term terrestrial and marine space mapping and promotion should be embedded with coordinated hazard and risk management of an STI enabled integrated

ecosystems framework. The establishment of the Philippine Space Agency (PhilSA), is a significant STI enabler and influencer on both the protection of the environment and biodiversity resources and utilization for competitiveness.

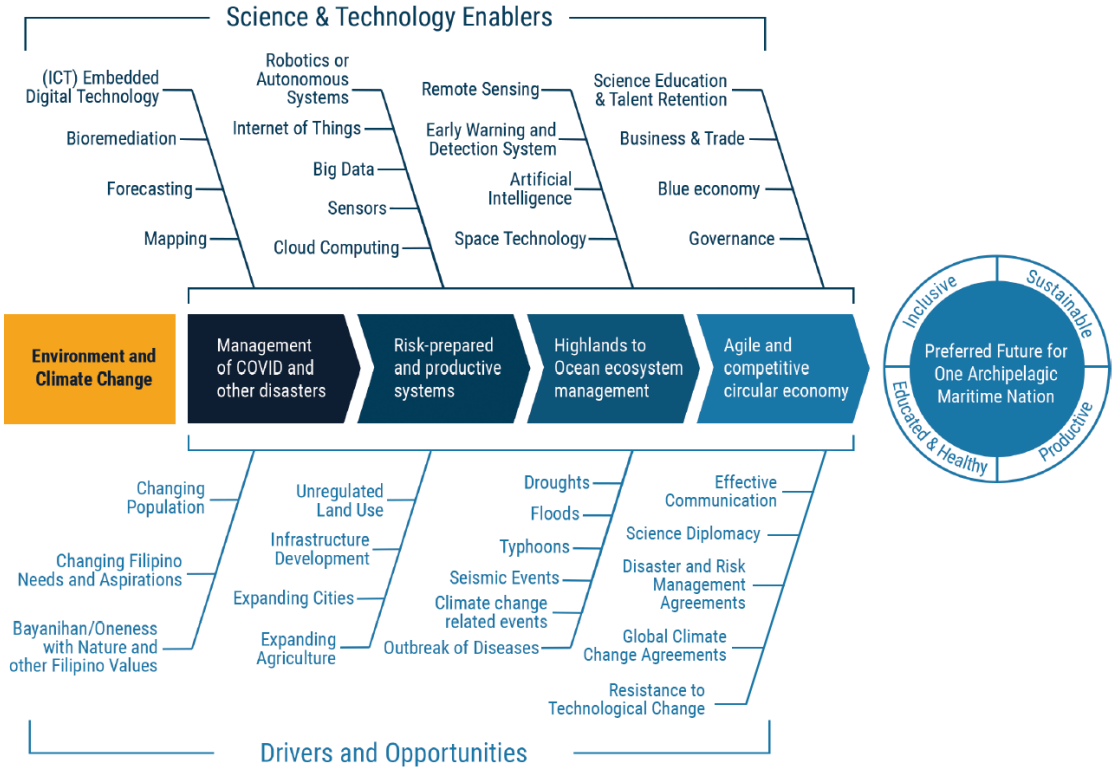

Figure 6.2_2. Environment, Climate Change, and Space Exploration Cluster Map

Philippine demography and population health and well-being will weigh heavily on the progress of this cluster. Poverty incidence, if not curbed or stopped significantly can continuously negatively impact the environment/ resources particularly, in the area of pollution. Filipino values like the bayanihan spirit nationalism/love of country of our forefathers and our indigenous tribes "oneness with nature" should be harnessed formally and informally especially among the youth. Effective science communication must be pursued.

At the regional and global level, climate change issues and management will continue to be a major influencer on the environment and biodiversity. Regional and global agreements and guidelines on manufacturing, business and trade, among others, will be guided by climate change management and carbon footprints and credits. The Philippines should be able to participate well and effectively in the consultation and discussions of these S&T issues at the regional and global arena using "science diplomacy" and "diplomacy for science" with the present interests and future of the nation as priority.

S&T enablers in this cluster are related to the other clusters but with focus on specific needs and advancements in the areas of environment, climate change, and space exploration. Biotechnology and nanotechnology are

useful for innovations on multi-sensor and robotics/autonomous systems development. Information and communications technology will empower all aspects of operations in the cluster together with big data analytics and artificial intelligence. Terrestrial and marine integrated spatial planning and ecosystems management should be embedded with disaster management and technologies for early warning and mitigation. Applications (Apps) for technical and other stakeholders' use in disaster prevention and mitigation should be further enhanced. The Department of Science and Technology's GeoRisk Philippines that identifies landslide prone areas should be expanded to include other hazards and risks. The PhilSA should be strengthened with financial, infrastructure, and manpower support to enable the agency to perform its various roles in the protection and utilization of the environment and resources and climate change related problems of the country, navigation, and national security.

The overarching enablers for this and the other clusters should be the results of interlinked STI. Science education and talent retention to power up this cluster is in its infancy stage, including informal education. Governance of the environment and climate change impacts and use of space technology/ apps from the local/lowest level to the national level should be embedded in a vision of a "reinvented STI ecosystem" where currently, decision making is fragmented. The Business and Trade sector should be STI-equipped to meet local and global needs and opportunities in this cluster, and its plan of actions should include short and long term effects to the environment and climate change impacts.

A game changing enabler is the blue economy platform. It espouses the inclusive growth of the population through the sustainable use of living and non-living resources and protection of coastal and marine environments. A circular economy with production-consumption rate balanced estimate is vital in a competitive, inclusive, and sustainable maritime nation.

The cluster road map does not show years to delineate the different stages towards the end of the road or goal. This is to encourage the hastened but careful and coordinated analysis, planning and implementation of actions to reach every stage in the least possible time while considering the interactions and interrelationships with the other operational areas/clusters. The first stage in the map is called the "COVID pandemic, and other risks responsively managed", an ongoing period where effective "survival" adaptations in this highly disruptive stage are critical to enable us to proceed to the next stage . The second stage is called "circular economy with anticipatory disaster risk management" The third stage should also overlap or integrate early with the previous stage and this is called " agile and competitive circular economy."

Food, Nutrition, and Health Cluster

For the Food, Nutrition, and Health Cluster (Figure 6.2_3), the initial goal is similar to the Environment, Climate Change, and Space Exploration and the Built Environments clusters. This is followed by policy reforms in health and agriculture, revitalized government institutions, inclusive precision health and agriculture, and universal health care and food security.

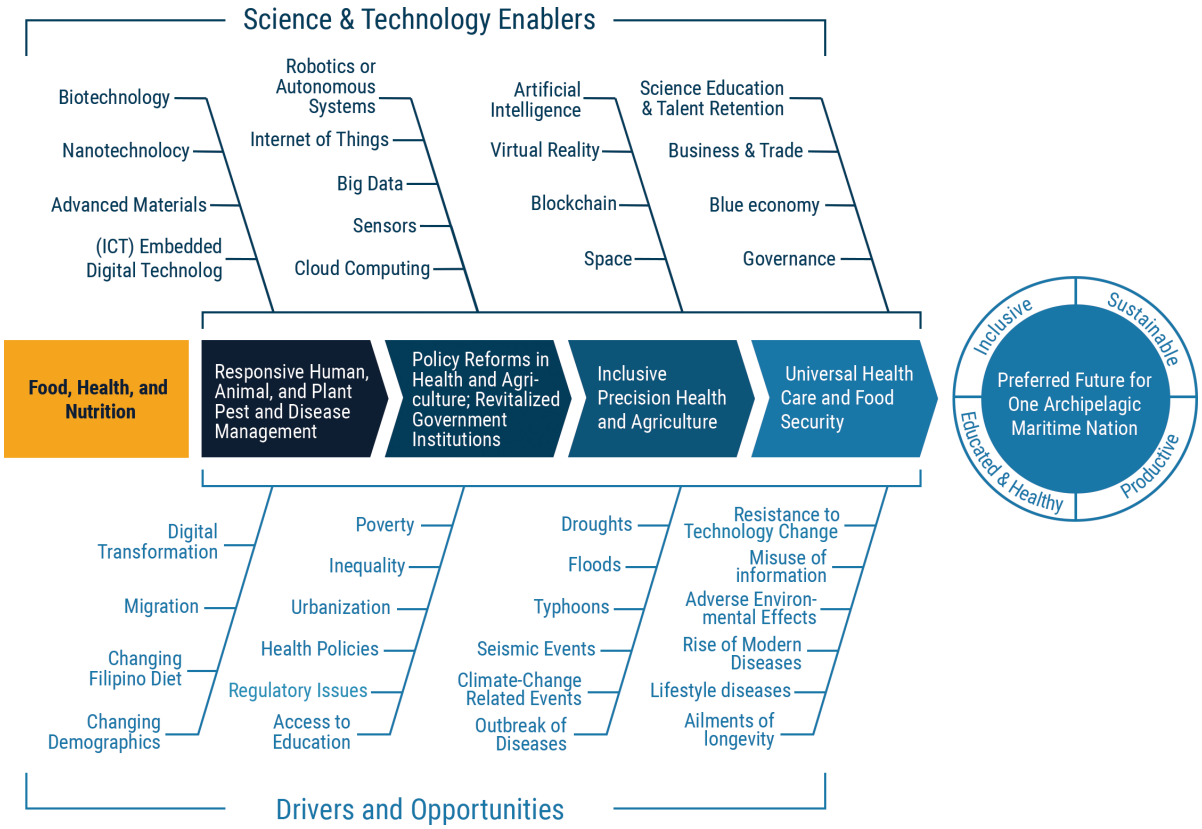

Figure 6.2_3. Food, Nutrition, and Health Cluster Map

The indicators used to measure poverty are based on counting the "individuals and families whose income fall below the poverty threshold as defined by NEDA and/or cannot afford in a sustained manner to provide their minimum basic needs of food, health, education, housing, and other essential amenities of life" all of which are embodied in RA 8425 (Mapa 2020). Thus, concerns about food, nutrition, and health are paramount in the quest towards poverty elimination.

The scenario for Food, Nutrition, and Health from 2021 to 2050 spans a period of close to 30 years towards a food secure nation that enjoys full benefits of universal health care both of which are critical to attain the goal of being a prosperous, archipelagic, maritime nation and being the healthiest nation in the world.

The role of agriculture in improving the status of health and nutrition of our country has not been fully realized. According to Fan (2011) agricultural growth should consider its impact on health and nutrition by devising strategies that will "minimize risks and maximize the benefits to nutrition and health across the entire value chain, from production to consumption."

This scenario starts in the COVID-19 pandemic setting that has caused widespread suffering across sectors and countries including the economic downturn that has increased those experiencing hunger and poverty. Thus, the challenge is for science, technology, and innovation to provide the tools to responsibly manage the incidence of pests and diseases in humans and in animals and plants with high economic value and at the same time, set the stage for the revival of the economy, followed by improvement in productivity to create new wealth in a sustainable manner.

Living systems are the pillars of agriculture and health. The state of the living systems is in turn affected by the materials obtained by the organism to provide the structure and energy to sustain the processes to keep the living systems functioning within the influence of the environment. In addition to the traditional disciplines of systematics, physiology, anatomy, morphology, microbiology, virology, evolution, among others, S&T have progressed in the last two decades to provide the basic tools to better understand life's processes such as:

- Genomics
- Structural Genomics
- Functional Genomics
- Transcriptomics
- Proteomics
- Metabolomics
- Structural Biology
- Synthetic Biology
- Pharmacogenomics
- Pharmacogenetics
- Nutraceuticals
- Nutrigenomics
- Nutrigenetics
- High Speed, high-capacity chemometric methods
- High Speed, high-capacity computing
- Computational biology
- Quantum biology
- Quantitative biology
- Internet of Things (IoT)
- Sensors
- Big Data
- Artificial intelligence (AI)
- Nanotechnology and new materials
- Phenomics
- Autonomous Systems and Robotics
- Structure and Function of novel molecules
- Sociology
- Anthropology

Access and expertise in the above disciplines and their accompanying research techniques allow us to see more, detect more, and sense more in order to provide greater insights and in-depth approaches to innovate.

Innovation Stage I: Responsible Management of the COVID-19 Pandemic and other Pests and Diseases Affecting Human, Livestock and Poultry, and Food Crops

The starting point of this scenario is in the midst of the COVID-19 pandemic, accompanied by the infection of a significant part of the local swine industry by the African Swine Fever and isolated instances of Bird Flu, a poultry disease which can affect humans. The severity of the impact of the COVID-19 pandemic has disrupted the supply chain and dampened the demand in both the agriculture and health sectors.

Observers consider the COVID-19 pandemic mainly as a health problem and the challenge has been to balance the need to contain the spread and to continue whatever economic activity may be possible. The weaknesses of the health care delivery system in the public and private sector in the Philippine have been exposed and interventions had to be undertaken with urgency to reduce morbidity and mortality. The science community, especially in the health and life sciences, provided science-based advice as they were able, and the lack of expertise and facilities in human vaccine production was apparent. The establishment of the information infrastructure to monitor the spread of COVID-19 infection proceeded quite slowly and was often overtaken by events. During the recent outbreak, many COVID-19 patients found it difficult to gain admission to hospitals, and the health care workers found themselves overworked.

The challenge has been the need to balance the protection of the population's health and the economy. This is to be based on a robust surveillance system, as detailed as possible, by using digital technology (information and communication technology) to establish the information infrastructure that will monitor food safety and supply and the ability of our health care delivery system to respond to the pandemic.

Traditional food supply chains became vulnerable to supply fluctuations due to disruptions in storage, transportation and services. Similarly, the health care delivery system had to try its best to manage the situation in the light of the constraints.

Information about the extent of the infection, whether they be in humans, livestock and poultry and food crops, is crucial in designing interventions to prevent the further spread of the pest or pathogen. In addition to the surveillance system which consists of testing, contact tracing, and physical facilities for isolation and quarantine, the use of scientific tools to identify the pathogen or the pest, to treat infected persons, livestock and poultry and food crops, to determine the containment measures and the right treatment using social mechanisms, physical barriers, drugs, chemical compounds and devices. These present opportunities to develop the know-how and innovate in response to the needs of the times.

Research and development activities have not been exempt from the disruptions caused by COVID-19. Likewise, the educational system has been confronted with the possible loss of learning at all levels. Delays in R&D activities and localized infestation by pests and diseases in the agriculture and health sector has imposed additional constraints in attaining food security.

Innovation Stage II: Reviving the Economy: Policy Reforms in Health and Agriculture, Revitalized Institutions and Government Agencies

This innovation stage will revive and consolidate the gains achieved before the pandemic. Previous initiatives that have been disrupted in various ways will be reviewed and those that will lay the ground for a high-growth development will be set in motion.

The COVID-19 pandemic is believed to be an opportune tipping point to revive the economy towards our preferred future. The role of the agriculture and health sector will be vital to this effort because a workforce that has access to nutritious food and universal health care will be able to make the difference in reviving the economy using the tools of S&T. At this transition period, we expect to free ourselves from the constraints imposed by the pandemic and start mobilizing the population. This time, there will be new modes of social interaction among co-workers within an institution. Precautions will still have to be taken to prevent a resurgence of a pandemic or even an epidemic. The supply chain for goods and services will be revived to pre-pandemic capacity gradually.

The magnitude of the challenges that have to be managed can be gleaned from the population figures. As of the early part of April 2021, the World Population Review (2021) reports the Philippine population at 110,729,412 and projected to reach 144,488,158 by 2050, increasing at an annual rate of 1.39%, at one birth every 14 seconds. The population figures alone are daunting both in terms of coping with the food supply and the health care facilities. The increase in population will put pressure on our food supplies, educational facilities, and the health care delivery system to serve more than 7,000 islands and a vast maritime territory (World Population Review 2021).

Both our food system and health care system will have to be transformed after COVID-19. The features of an ideal food system are as follows (International Food Policy Research Institute 2021):

- Efficient – provide incentives and remove hurdles to deliver efficiencies in the supply chain
- Contribute to global health – provide affordable, nutritious foods, and guarding food safety
- Inclusive of small holder farmers and marginalized groups such as women, youth, the landless and refugees and displaced people
- Environmentally sustainable using technological innovations and governance approaches to conserve and protect natural resources and mitigate climate change

- Resilient – able to bounce back quickly from health, climate, and economic shocks, providing poor household with stable livelihoods that protect them from shocks

Reviving the economy is not just a mere reversion to pre-pandemic conditions. The revival stage must lay the ground for the transformation into a high growth development where opportunities to create new wealth will be open to all sectors of the population. This is the time to identify growth points by a careful and rigorous reading of both the domestic and global market for new and next generation products in food and health, especially those derived from marine sources. A sharpened focus on high value-added products in agriculture and the enhancement of health care services should now be initiated to set the stage for high growth development.

Furthermore, attention should be given to promote urban agriculture in the major urban centers in the Philippines such as Metro Manila, Metro Cebu, Davao City, Cagayan de Oro City, and Zamboanga City.

In addition to enhancing the nutritive content of food crops, the global market for plant-based ethnic food, flavors, spices, colorants, essences and drugs and other non-food products from plants and microbial sources must be explored and next generation products should be developed.

On the enhancement of health care delivery, the rational development must now be initiated to improve the carrying capacity of our health care system towards providing universal health care to an archipelagic and maritime nation. The activities should commence to further the application of technologies in IoT to monitor patients and status of health in communities, the use of big data and AI to analyze and gain insights on the efficiency and efficacy of measures leading to universal health care, the use of nanotechnology and new materials for medical products and devices, biotechnology to understand the nature of infectious and non-communicable disease, and the use of robotics as caregivers and delivery of treatment for infectious diseases. These are just a few examples of the vast opportunities to lay the ground for a high growth development agenda.

Innovation Stage III: High Growth Development: Inclusive Precision Health and Precision Agriculture

This stage shall involve a technology explicit agenda to develop a prosperous economy by creating new wealth with a highly skilled workforce, the outcomes of which are enjoyed all over the archipelago and fully cognizant of our maritime resource base. The following shall be the basis of the development agenda:

- Recruitment of talented, ingenious, and adaptive workforce – access to high-quality education in the Philippines and abroad; recruit talent from global market
- Economic efficiency-reliable supply of energy, efficient transport system, healthy workforce, provision of a reliable supply chain

especially for essential goods and services, all consistent with a circular economy
- Trade facilitation – major player in the global biocommerce market, functional national quality infrastructure, upgraded products in the services sector
- Food security – access to affordable, nutritious food, well-managed farms
- Environmental protection – establish the components of the circular economy through well-designed systems in the agriculture, industry and services sectors to minimize wastage and air, water, and land pollution, including functional recycling of wastes and obsolete materials
- Disaster risk management- all human settlements deployed in areas of low risk to natural disasters and
- Technology for national defense – increase investments in R&D of technologies related to national defense and national security. This includes the continuing issuance of the national identification card, surveillance of national territory against foreign aggression and illegal operations (logging, smuggling, etc.) and attract investments in a defense industry.

High growth development will depend on connecting and engaging the elements of the archipelago, the intensification of efforts to harness the maritime resources, and access to new knowledge through S&T. At this point, the population of the Philippines shall have increased to around 130 million and the Industrial Revolution 4.0 shall have transformed nations to deal with highly technological societies.

The Philippines shall now have sorted out the food-nutrition-health nexus and the nutritional status of the population shall have been improved considerably with stunting and malnutrition significantly diminished. The commitments of the Philippines in the targets set in the SDGs related to food and agriculture and the Climate Change Agreements shall have been accomplished.

At this point the manufacturing sector for high valued products, especially in the biocommerce market, shall be fully activated and fully coordinated with the raw material supply chain coming from agriculture and maritime resources. Likewise, the installation of clean energy sources shall be nearing full-national coverage and the cost of energy shall have gone down. Farms shall have been consolidated and operated profitably. The services sector such as tourism, health care, business process operations, and other new business prospects shall be efficiently operated.

Innovation Stage IV: Competitive Economy: Universal Health Care and Food Security

The capacity to extract, characterize, purify, and define the composition of raw materials and products in agriculture and health, especially from maritime and archipelagic sources, shall have been established within the

Philippines. This is expected to be the most significant contribution of S&T in gaining the advantage so vital is a competitive economy. The in-depth knowledge gained about these raw materials and products is the very foundation of a resilient and agile society allowing all sectors to plan on a roadmap to take remedial steps to get out of the rut or to minimize the effect of the disruptive forces that have inhibited or slowed down growth. Agility and resilience shall be the defining factor of a competitive economy in the midst of many risks and uncertainties and the frequent incidence of black swans or unexpected events. In other words, the reliability of the supply chain shall be a determining factor in sustaining business.

This stage shall see the manufacture of next generation products processed from marine sources: new, rapidly biodegradable materials, nutritious food, drugs, cosmetics, new biomaterials, etc. The intensified efforts in the search for unusual microorganisms shall bear fruit in terms of new biomaterials, new bioprocessing agents (heat-tolerant, minimal product feedback inhibition), new molecules, new reliable detection techniques for infectious microbial agents in human, livestock and poultry, and food crops. Furthermore, the features of an ideal food system shall have been substantially realized.

By 2050, governance shall be transformed to fit the mode of production of new wealth. The human resource and workforce will now be skilled to manage advanced technologies. Decisions shall be science-based taking into consideration the welfare of close to 150 million Filipinos whose nourishment and health must be assured. This will require massive resources that will be derived from new wealth, enhanced by the sustainable exploitation of maritime resources and the increased efficiency in the transformation of agricultural, maritime, and microbially-based products into profitable business ventures able to survive competition in the global biocommerce market and in the provision of health care services not only for the Filipinos but for patients coming from the region as well.

The Philippines will benefit from a healthcare ecosystem that maximizes value by empowering the patients, the providers, the social health insurance and the commercial insurance to achieve synergy through efficient governance and technology.

The proposed stages and timelines for tasks where STI will provide major inputs are in Figure 6.2_2.

A significant increase in the per capita GDP income shall have been achieved through an inclusive development strategy that considers our archipelagic and maritime resources as the platform. The survival, security and enabling needs of the Filipino people shall have been substantially provided and poverty levels shall be one of the lowest in the world.

Table 6.2_1. Proposed Phased Development of STI in Food, Nutrition, and Health

Themes	2021-2022	2022-2028	2028-2034	2034-2040	2040-2046
Policy	Review of existing policies, legislative action, and laws that negate health for all	Address issues resulting from increased number of working women Multisectoral institutionalization of the "health in all" policy approach.	Establishment of a model healthy community as proof-of-concept and basis for scaling up changes Model community linked with Bidani (Nutrition communities)	(none indicated)	Whole of nation approach to population management
Information Education Communication Campaign		Aggressive campaign against fast food eating habits Aggressive government intervention in shaping the diet of people and children (i.e., feeding program, disasters, etc.)	Promotion of healthy fast food through adoption of Japanese "Bento"		Education for children-should be digital in the form of games/Digital delivery of content/ message appropriate to the current audience facilitated by ICT and Artificial intelligence
Food production and delivery system	Intensify production of vegetables and fruits	Improvement of agricultural product delivery system Government to mediate a better distribution system through incentives Incentivize backyard farming and farming in general	Online fresh produce/ market (expansion and increased use) of e-Kadiwa Strengthen LGU's role in farm to market – provide seedlings for free; buyer of the produce (LGU will commit to buy produce; provide transportation to the market; identify the market Real farm to market distribution in place (removal of middleman; can be replaced by government)		Technology market for food, nutrition, and health – similar to electricity market, incentivized and made competitive to lower the costs
Healthy Lifestyle		Create an environment supportive to sustain healthy lifestyle Caloric labelling of fast food products as guide for healthier living Incentivize healthy food and impose sin tax on fast food Food menu reviewed	Personalized diet prescribed and connected to the food distribution systems		

Table 6.2_1. Continued

Themes	2021-2022	2022-2028	2028-2034	2034-2040	2040-2046
Technology		Innovation in infrastructure and physical sete-up for health and food systems	Online fresh produce/ market (expansion and increased use) of e-Kadiwa Personalized diet prescribed and connected to the food distribution systems Comprehensive health insurance system in place e-finance (financing technology in the health sector)		Education for children-should be digital in the form of games / Digital delivery of content/ message appropriate to the current audience facilitated by Information and Communications Technology (ICT) AI Technology market for food, nutrition and health – similar to electricity market, incentivized and made competitive to lower the costs.
					2046-2050 **Filipinos healthiest in the world**

Energy and Water Cluster

The recovery stage from the pandemic of the Energy and Water cluster aims for the provision of water and energy in off-grid areas. Risks from other natural and man-made disasters should be managed responsibly at this stage. By the second stage, unhampered supply of safe water and energy should be achieved. These resources should be calculated and maintained based on island or regional space planning and implementation. This is critical for transition to the next stage. The third stage, "Sustainable Consumption and Production" builds on the gains of the first two stages through the RDIs for effective clean technologies for water and energy sourcing, storage, and distribution. In this stage, reliance on water and energy supply should consider cybersecurity since these technologies and processes will need ICT and IoT. The fourth stage is geared towards "Universal Access and Security" scenario that can be reached when the drivers and opportunities unique to the cluster are managed harmoniously.

Considering the natural features of the country, the major drivers and opportunities in this cluster are shared with the other clusters, particularly the Environment, Climate Change and Space Exploration cluster, e.g., Seismic events and seasonal typhoons, exacerbated by climate change. Thus, floods and droughts can be experienced in different parts of the country. Local or regional planning and implementation for production and consumption rates are needed for both water and energy. Outbreaks of diseases in humans and other living organisms can be offshoots of water and energy problems such as in prolonged EL Niño and La Niña. Pollution from the land into the freshwater and marine waters constitute the significant threat to water safety. Physical changes in the watershed such as deforestation will negatively affect water availability.

Socio-economic drivers and opportunities also include population/ demography changes and the shift in needs for water and energy coming from urbanization and economic growth. Planning and implementation should address uneven capacity of production-consumption rates and affordability at the local and regional levels. Independence of islands or regions in production capacity can result to overproduction in one and underproduction in another. Thus, measures must be undertaken to allow access to water resources at the inter-island or inter-region level.

At present and in the next few years the Philippines would have to make do with conventional technologies or enablers that will hopefully leapfrog to locally produced or adopted clean technologies soon. Available clean technologies for water and energy have been mostly developed in industrialized countries. To meet the present and future requirements of the country some of these clean technologies could be acquired via foreign direct investment, imports, and licensing arrangements. Further, these technology transfers involve importation of hardware and software, sharing of knowledge, and adaptation of technologies to local conditions. Tax incentives and other financial/economic support for business/industry or Public-Private Partnership or other future business/investment models are prerequisites to facilitate development of water and energy sectors. The "rule of law" should prevail in the access and distribution and water particularly in the underserved and unserved areas. Formal and informal science education from the earliest years could provide marked positive influences not only in the increase of S&T manpower but assist in making the Filipinos "science cultured" and "sustainability conscious."

Maintaining domestic water quantity and quality using indigenous technologies like rain harvesting can be enhanced by innovations in proper collection and storage. Local communities should be made aware of climate changes affecting the timing and amount of rainfall the excess of which can also result in flooding. Establishment and proper maintenance of water reservoirs in strategic places for domestic, irrigation, and electric generation should be given priority. Likewise continued improvements and wide use of locally available clean technologies for energy such as solar and wind energy should be supported based on a framework/space mapping that considers local hazards and risks.

Precision agriculture/aquaculture using an array of sensors linked with real time sensors for water quality and quantity would be a great boost to the sustainability and resilience of water supply. Biotechnology and nanotechnology will enable the development of these sensors and renewable energy. The development of manpower and infrastructure in this cluster should also be closely linked with the other clusters since the requirements for water and energy are universal and important in a circular competitive economy where wasteful and duplicating processes are minimized or removed.

The Blue Economy platform will play a pivotal role in this cluster and other clusters towards the achievement of "a prosperous, archipelagic, maritime nation" that is inclusive, sustainable, and competitive with healthy and productive citizens. The approach has dual objectives which are: the sustainable utilization of both living and non-living marine resources and the inclusive development of the people. The immense impact of the approach to coastal and oceanic transport, energy, sustainable tourism, fisheries and aquaculture/food security, habitat (land and water) protection, water supply (desalination) should be realized through a strategic/aggressive, whole-of government approach. A critical review of existing laws, policies and practices for appropriate revisions and/or simplification in support of the Philippine blue economy has to involve key representatives from maritime law and enforcement, marine science and education, maritime and other related businesses, and national security, among others.

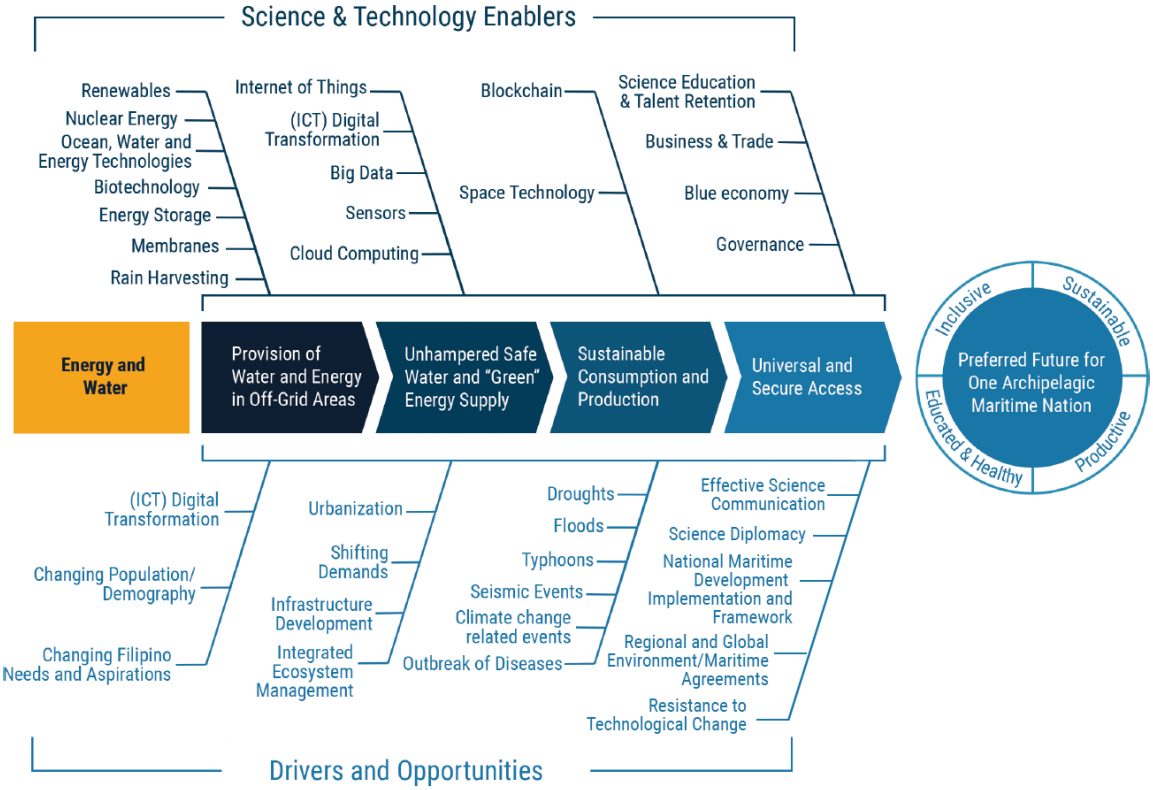

Figure 6.2_4. Energy and Water Cluster Map

Built Environments Cluster

As mentioned earlier in this report, the indicators used to measure poverty are based on counting the "individuals and families whose income fall below the poverty threshold as defined by NEDA and/or cannot afford in a sustained manner to provide their minimum basic needs of food, health, education, housing, and other essential amenities of life" (Mapa 2020). Based on the Family Income and Expenditure Survey in 2000, 2003, 2006 and 2009, the average percentage of the minimum income that is spent for non-food needs is only about 30% including expenses for housing, transportation, and

communications. About 70% is spent for food (Mapa 2020). Thus, to enable communities to enjoy healthful, safe, and pleasant living conditions, concerns the provision for shelter and infrastructure must be addressed if we are to significantly reduce the incidence of poverty in the country. These concerns are embodied in RA 8425.

The initial setting of the Built Environments cluster (Figure 6.2_5) is the COVID-19 pandemic that has caused widespread suffering in all sectors and in all countries and exposed in a more pronounced manner, the weaknesses, and inequalities that have been lurking in our midst for many decades.

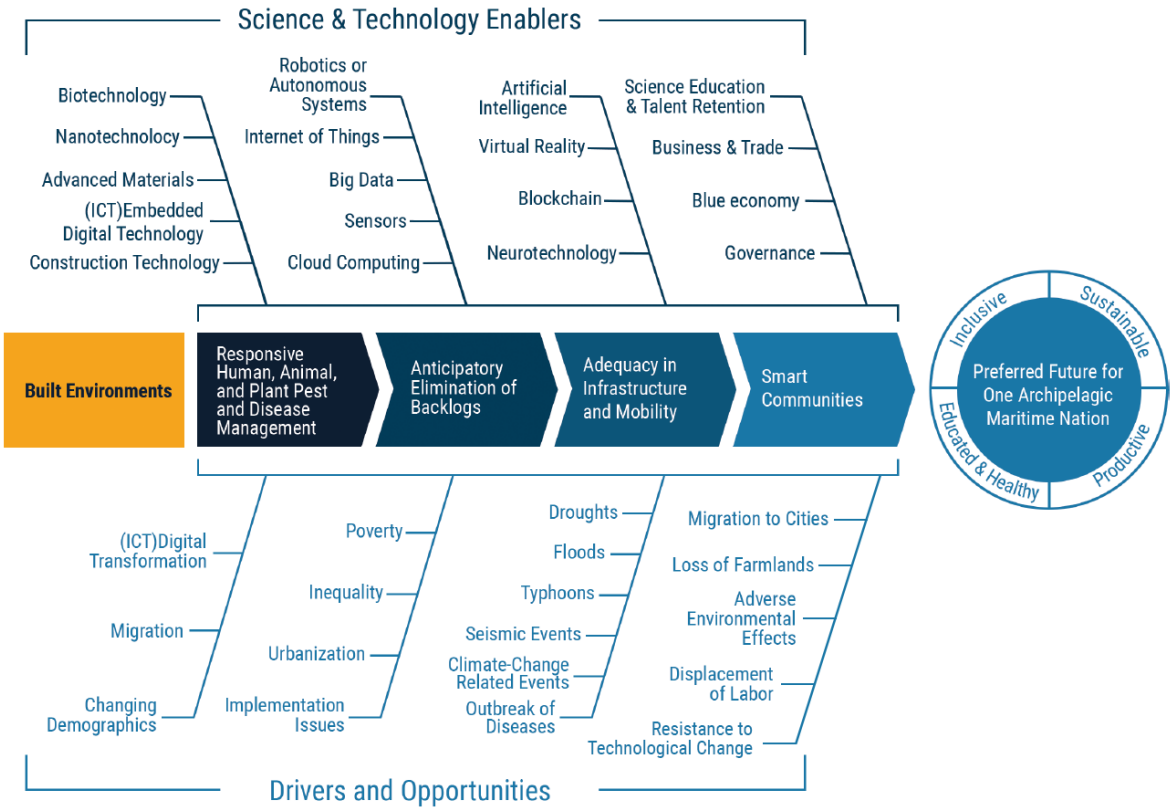

Figure 6.2_5. Built Environments Cluster Map

The challenge is for STI to provide the tools to responsibly manage the incidence of pests and diseases in humans, livestock, and poultry and in the food crops. The containment of the spread of these diseases should set the stage for the revival of the economy, followed by improvements in productivity to create new wealth in a sustainable manner. However, the water and power provision will be discussed in the scenario on water and energy.

Provision for safe and comfortable shelter engenders a sense of security for the Filipino family, whether they reside in urban or rural settings located inland or along the coasts. Likewise, civil infrastructure and transportation are critical factors in achieving economic efficiency, trade facilitation, and effective governance. This scenario will take into account the unique archipelagic and maritime features of the Philippines.

Civil infrastructure systems provide the lifeline of society. Human activities are supported by civil infrastructure systems or built environments that are managed, designed, and analyzed using the S&T tools. Civil infrastructure systems extend beyond civil engineering in order to construct safe and comfortable shelters in urban and rural settings, support economic activities and enable social interaction. Civil infrastructure systems deal with how the different built environments function together including electric power, fuel supply, water and wastewater distribution and management, communications, transportation, waste disposal, and shelter in urban and rural communities located inland or along the coasts and will harness the following STI areas:

- Engineering: civil, mechanical, electrical, chemical, sanitary, electronics
- Architecture
- Urban planning
- Sociology
- Chemistry
- Physics
- Biology
- IOT - detection of phenomenon using sensors, sending signals and responses, generating data for analysis
- Big Data - tools to measure massive amounts of data to gain insights, see patterns, and analyze e.g disaster risk management
- AI - attempt to migrate intelligence to machines, may trigger changes in modes of production, mindsets, and means of achieving social productivity
- New materials and nanotechnology - discovery of unique physical and biological properties of nano-scale matter with wide application in medicine , environment,energy, etc.
- Autonomous systems - automated vehicles, drones, robots
- Biotechnology - redesigning organisms to produce substances of economic value such as fuels, medicines, easily biodegradable biomaterials
- Structural dynamics design
- Resilience engineering
- Sensors
- Geographic information systems
- Spatial analysis
- Transportation systems
- Statistics
- Environmental science

Innovation Stage I: Responsible COVID-19 and Other Pests and Diseases Management - The Role of Built Environments and Digital Transformation

This innovation stage will operate in the COVID-19 pandemic setting. The challenge for the present is for built environments or civil infrastructure to mitigate the spread of COVID-19, as well as other pests and diseases that affect agriculture. Thus, the urgent task is to design and construct permanent

or temporary built environments to support the timely containment and treatment of infectious diseases with the assurance that these public infrastructures are also safe for use during pandemics or natural disasters. This includes the retrofitting of rooms and grounds in schools so that students can attend school safely, the upgrading of hospital facilities, instituting measures in public transport and public places to enable compliance with physical distancing requirements. Due to restrictions in movement, it is also important to maintain the reliability of communications such as high-speed broadband to avoid disruption of transactions. Furthermore, wastewater disposal will be an important intervention to prevent the spread of infection and contamination. Currently, the Philippine government with the contribution of the private sector, is engaged in constructing additional healthcare facilities that comply with global standards.

A major effort will have to be initiated on the construction and retrofitting of shelters including homes and office rooms as this will require a large capital cost. Health protocols will have to be strictly observed in densely populated communities to minimize congestion especially in areas where there are many informal settlers living in single-room dwellings.

Observers note that the pandemic has hastened the adoption of technology-based strategies, notably ICTs, to cope with the unexpected disruption of activities (MIT 2021). The increase of online transactions, classes and meetings lessens face-to-face contact in order to control the spread of infection. Unfortunately, with large numbers of schools and business establishments shifting to online transactions and activities, the wireless telecommunications backbone has been unable to cope with the demand for more bandwidths. While adjustments are ongoing, the changes will not happen overnight.

During the pandemic, where lockdowns are frequently imposed, use of digital technology tools for identification, contact tracing, data gathering, financial transactions, and even the conduct of meetings has enabled the economy to function and social interactions to proceed albeit in a reduced manner. These tools should be made available to as many Filipinos as possible and access to quality wireless communication should be pursued relentlessly using a package of technologies.

The timely delivery of goods and services has been affected by the lockdowns as the transport services have been constrained to considerable downsize their operations. Moreover, the health protocols impose limits on the passenger load of the public transport system. The impact of this slowdown has been felt strongly by the micro, medium and small-scale enterprises and productivity remains low in business establishments, farms, factories, and the service sector.

Innovation Stage II: Revived Economy: Anticipatory Elimination of Backlogs

With the pandemic substantially controlled, this stage will revive and consolidate the gains achieved before and during the pandemic and attend to the backlog in the projects that have been delayed by the pandemic and other reasons. Previous initiatives that have been disrupted in various ways will be reviewed and those that will lay the ground for a high-growth development especially where significant progress has been achieved in the construction of vital infrastructure to enhance mobility and connect the islands in the archipelago.

Digital Transformation

The groundwork for digital transformation shall be intensified. Digital transformation"is the incorporation of modern technologies into an organization's processes and strategies to achieve business goals such as improving customer outcomes or operational agility" (MIT 2020).

The opportunities for innovation and stepping up digital capabilities are as follows (MIT 2020):

- Establishing a nationwide digital communications backbone that would reach all the islands and remote communities. This is to be coordinated with the energy sector with due consideration of operating microgrids.
- Improving the conduct of online learning- reinventing the way we learn
- Automating Manual Processes
- Accelerating Digital Capabilities of the citizenry
- Adopting a modern application development platform
- Using infrastructure or platform for IT security
- Expanding cloud services adoption
- Expanding agile and continuous-delivery methods
- Increasing investment in mobile applications
- Creating digital-first customer experiences
- Expanding application development teams

The digital transformation of Estonia is a model worth studying. After the Soviet Union was dismantled, the government of Estonia focused investments in digitalizing the public sector which allowed businesses to be registered and operated online to avoid the long processes required by the bureaucracy. This strategy generated jobs and tax revenue (Patricolo 2017; Pickup 2018).

It is expected that even after the restrictions of the pandemic have been lifted, remote work will still be the major mode of delivery of outputs by the workforce. The opportunities for innovation mentioned above are expected to keep businesses afloat through secure online workflow, and the development of continuous delivery applications for new products and services. These interventions are expected to rebuild the economy and set the stage of higher growth.

Shipping

Being an archipelagic country, the Philippines counts on the maritime industry to transport goods and services in both the domestic and global market. Shipping provides the major links among the islands of the archipelago. In a study made in 2006, water transport accounted for 42% of the freight in the country and in 2012, carried 74 million tons of cargo and 50 million passengers. Thus, with the lifting the post-pandemic, there will be opportunities to revive and improve maritime transport in the areas of domestic shipping, overseas shipping, upgrading of maritime manpower, shipbuilding and ship repair as well as the improvement and expansion of port facilities in cargo handling and the cold chain to service 8,112 seafaring vessels of various types that ply the Philippine seas (UN-ESCAP [date unkown]).

Shelter and human settlements

Responding to the housing backlog will be a great challenge during the recovery period. Increasing the production of houses at an affordable cost may have to be subsidized for selected beneficiaries. This could be complemented by mobilizing and generating financial resources to support end-users. (Padojinog 2020). While there are ongoing projects to provide housing for the low-cost segments, the backlog is still considerable at 5,880,630 units in 2015 inclusive of the socialized, economic, low, medium, and high types but not including 786,984 units for those who cannot afford. It is projected that by 2030, the total housing need will be 12.3 million units. (Padojinog 2016)

The goal is for S&T to provide the knowledge to innovate so that the cost of building houses/shelters will be affordable. This will involve the search for new materials from renewable sources and the discovery of new technology to produce cement with low carbon footprint. Furthermore, shelters should be intelligently designed to withstand the increasing frequency of extreme weather conditions and earthquakes. Highly populated living spaces such as condominiums have to be designed to provide more open spaces.

About the design of communities, especially in urban areas, the provision for walking, cycling and access to reliable and efficient public transport system have to be taken into account such that people, rather than vehicles, will be given priority for safe and healthy living. Furthermore, construction activity must consider the use of materials with low carbon footprint. Mass transport facilities and those the logistics to support the supply chain will benefit from well-designed, well-built roads, bridges, ports, and airports. All these to be carefully designed for resilience in the light of the occurrence of typhoons, floods, drought, and earthquakes. The durability of the materials used under tropical conditions must be subjected to tests and quality assurance. Preparations must be undertaken to cope with the production and maintenance of battery-powered electric vehicles.

Innovation Stage III: High Growth Development: Adequacy in Infrastructure and Mobility

The recovery phase has provided the foundation for high growth. Gains in the digital transformation of the economy and in governance will have established efficient systems of workflow. Efficiency will be the hallmark of the third phase of innovation.

High growth initiatives in digital transformation shall consist of the following including those cited earlier (MIT 2020):

- Sustained development of a nationwide digital communications backbone that would reach all the islands and remote communities. This is to be coordinated with the energy sector with due consideration of operating microgrids
- Automating Manual Processes
- Accelerating Digital Capabilities of the citizenry
- Adopting a Software-defined network
- Accelerating cloud migration
- Adopting a modern application development platform
- Expanding a multi-cloud strategy
- Using infrastructure or platform for IT security
- Expanding cloud services adoption
- Expanding agile and continuous-delivery methods
- Increasing investment in mobile applications
- Creating digital-first customer experiences
- Instituting “secure-by-design” application development
- Adopting a “cloud-first” application policy
- Expanding application development team

These developments in the digitalization of the economy are expected to accelerate the growth of agriculture, industry, and the services, with innovations supported by a vigorous R&D program in government and the private sector. The workforce shall deliver their outputs enthusiastically, knowing fully-well that their minimum basic needs are seriously attended to by the government and the private sector.

Backlog in housing, construction of ports, airports, road networks, and bridges shall have been significantly corrected with technologies that have a considerably lower carbon footprint.

This third phase of innovation will harness the highly trained critical mass of the workforce to sustain the momentum gained in the recovery phase with regard to shelter, transportation, and infrastructure. A maritime highway that links every part of the archipelago will enhance the participation of more communities in productive economic activities. Traffic flow of air, sea, and land transport shall be professionally managed and considerably improved. This maritime highway could possibly be linked with the proposed ASEAN maritime highway that is highly connected by a series of ferries and roll-on-roll-off transport mode.

Satellite-based remote sensing technology will monitor in real time air quality, water quality, population density, land use, food production, the extent of damage during typhoons, floods, earthquakes, and many other future applications.

Finally, trade shall have been facilitated by a digitally transformed work environment with timely-access to information coupled with a globally-accredited national quality infrastructure including internationally-recognized testing laboratories.

Innovation Stage IV: Competitive Economy: Smart Communities

A competitive economy will thrive only where its workforce lives in communities that are secure, safe and healthy, designed to be resilient to natural disasters, climate change, pandemics, and various ecological crises. By 2050, these communities, in urban and rural settings, coastal or inland, should protect people's lives, sustain development gains, and drive positive change towards a future that is inclusive and prosperous. Smart communities have strong emergency response capacities in the form of support for planning, governance, capacity-building, funding, continuity of business, and delivery of services (Global Forum on Human Settlements 2020).

Smart communities are nature positive and climate-friendly, able to promote healthy lifestyles by strengthening the communication between stakeholders and government especially in the collection and analysis of data that will be the basis of important decisions. Food supply is critical and must not be disrupted even the times of economic downturns caused by pandemics and ecological emergencies.

Natural disasters and health crisis affect people the most especially those in coastal villages and the urban informal settlers. Thus, their living conditions must satisfy the minimum basic needs including healthful and safe shelters, reliable, secure, and well-maintained transport system and a sustainable civil infrastructure providing power, water, and access to the supply chain through strategically located roads and bridges.

A one-size-fits-all approach to the establishment of smart communities will not work. Future oriented studies on smart communities should consider the unique spatial (geographic and environmental) attributes, social, cultural, and economic factors. This will require a multidisciplinary approach involving S&T inputs, especially from the social sciences.

Smart communities must comply with the key principles of a circular economy(Global Forum on Human Settlements 2020):

- waste and pollution to be designed out of products and the living systems
- materials durable enough to be kept in use for as long as possible
- a regenerative surrounding natural system with adequate open outdoor spaces

These attributes are people-centered, sensitive to the mutual aspirations of the stakeholders. Special mention is made for communities along the coasts who derive their living from the ocean and aspire to live with the ocean in a sustainable manner.

A competitive economy is derived from a resilient and agile future that is dependent on S&T inputs to integrate people, water, nature, and the built environments. These are constructed ecosystems reinvented to support the well-being of all (Global Forum on Human Settlements 2020).

Towards an Integrated STI RoadMap

The integrated map (Figure 6.2_1), cognizant of the impact of the COVID-19 pandemic, combines all the clusters and their respective goals, from responsive human, animal and plant pests and disease management to a competitive economy. The progress of each cluster is determined by the interplay of S&T enablers and drivers and opportunities. Achievement of a competitive economy across clusters would bring the Philippines to its preferred future for a prosperous, archipelagic maritime nation that supports a technology-explicit development agenda that is inclusive and sustainable and nurtures a citizenry that is educated, healthy, and productive.

Launching the Priority STI Interventions in Support of an Archipelagic and Maritime National Development Agenda

Here are some suggested initial priority activities to be started in the recovery and revival phases of the STI roadmaps to consolidate and enhance the gains in STI highlighting the need for an archipelagic and maritime oriented national development agenda:

- Building a sustainable critical mass of STI human resources
    - Develop, attract, and retain expertise in dealing with the unique geographical features of the Philippine archipelago
    - Develop, attract, and retain expertise in marine science and related sciences
- Create the Philippine Council for Maritime, Marine and Aquatic Resources Research and Development (separate from PCAARD)
- Develop a focused R&D and extension program in maritime and marine sciences
    - Shipbuilding and drydocking
    - Transport Studies to achieve cost-effective efficiency
    - Mapping
    - Fisheries - modernization of fishing boats guided by GPS towards rich fishing grounds

- High valued products from biological resources from the sea (drugs, food, food additives, cosmetics, flavors, colorants, etc.)
- Inventory of biodiversity of our oceans and the archipelagic land mass
- Energy - wave, ocean thermal
- Mineral resources
- Desalination for domestic water use
- Pollution control
- Demographics, economic, and educational profile of coastal village
- Pollution control and abatement especially of tourist spots along the coast
- Reclamation studies
- Maritime safety and rescue system

- Develop a focused R&D and extension program to link and characterize with precision the biotic and mineral resources of our archipelagic land masses
  - Inventory of biodiversity (flora and fauna)
  - Inventory of mineral resources
  - Expanding the nautical highways
  - Deployment of ports and airports
  - Land use planning
  - Management of freshwater resources including pollution control and abatement in the major waterways and lakes; collecting rainwater
  - Urban and rural human settlements planning
  - Power distribution
  - Telecom infrastructure
  - Planned transport infrastructure to enhance correspondence in schedule of air, land, and sea transport services
  - Land degradation