NATIONAL SCIENCE, TECHNOLOGY AND INNOVATION ROADMAP (NSTIR) 2030

"Catalysis of Nigeria's Economic Growth and Competitiveness"

AN INTEGRATED ROADMAP 2017-2030

Developed by:

FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY (FMST)
Federal Republic of Nigeria
Abuja, FCT, Nigeria

June, 2017

NATIONAL SCIENCE, TECHNOLOGY AND INNOVATION ROADMAP (NSTIR) 2030

"Catalysis of Nigeria's Economic Growth and Competitiveness"

An Integrated Roadmap

(2017-2030)

developed

by

The Federal Ministry of Science and Technology
(FMST)
Federal Republic of Nigeria
Abuja, FCT, Nigeria

JUNE, 2017

FOREWORD

When I assumed office as the Minister of Science and Technology in November, 2015, I was very disturbed with the lack of interest among our pupils and students in the primary and secondary schools respectively for mathematics and science subjects. Also worrying, is the reluctance which some parents show when their children want to pursue careers in science and engineering. Arising from all these, our nation has depended so much on foreigners to execute projects in the area of science and technology, such that when we want to build important roads, bridges, airports, seaports, refineries and dams, we look for foreign expertise. Also, even for our telecommunications and the production of crude oil, the mainstay of our economy, we depend essentially on foreigners.

Today, there is no Nigerian Engineering firm that is competing for jobs in other countries of the world. Most worrisome is the unfortunate mindset of many Nigerians that things pertaining to science and technology should be left for other people who do not have our colour of skin. This explains why whatever equipment we need as a nation, what comes to our mind is to import from outside. I was determined that all these must change so that science and technology should play its rightful role in nation building.

Science, Technology and Innovation (STI) constitute the engine of socio-economic advancement for many countries. Investments in STI bring benefits to all sectors of a country's economy such as industrial development; infrastructure development; advanced and more convenient communication systems; energy system improvement; human health and environmental protection; and jobs for social system stability. All the highly-developed countries have invested intensively in STI and related research and development (R and D). They have created and implemented systems for harvesting and processing natural resources to produce goods; and developing facilities to serve their communities. They have devised ways of using the deliverables from STI to improve their governance systems and decision-making schemes. In this regard the President of the Federal Republic of Nigeria, His Excellency, Muhammadu Buhari, GCFR, has expressed his commitment to supporting fast-tracking of Nigeria's industrial and economic development through advances in STI.

As a prominent country in a highly competitive world in which advances and application of STI determine national wealth and affect the livelihood of citizens, Nigeria cannot afford to be left behind. The national goal of moving to a status of one of the top economies in the world is only achievable through the use of STI to modernize facilities, production systems and services. In the latest "World in 2050 Report" released in February, 2015 by PricewaterhouseCoopers (PWC) in which economic growth projections for thirty-two of the world's largest economies (constituting about 84% of the global GDP) are presented, the world economy is expected to grow at an average annual rate of

about 3% during 2014-2050. It is expected to double in size by 2037 and possibly triple by 2050. The Nigerian and Vietnamese economies are expected to become the fastest growing economies in the world over the 2050 timeframe. Nigeria is expected to rise from its 2014 rank of 20th to 16th by 2030 and 9th by 2050.

In order to attain the projected levels of economic performance and Nigeria's current economic development targets in many sectors as outlined in the full text of this document, investments in STI have to sharply increase within the next few years. Traditionally, Nigeria has invested very poorly in STI and R&D. Most of the countries that compete with Nigeria in the global market invest more than 2% of their GDP in research and development to create new products from their raw materials (and in some cases, imported) and market them globally to receive the advantages of domestic job creation, improvement of social services and elevation of national prestige.

Nigeria is now poised to do the same with this National Science and Technology Integrated Roadmap 2030 which has been developed after detailed review of the unmet targets of Nigeria's previous national economic development plans since independence in 1960 and the technological inadequacies that plagued them; assessments of STI needs of current roadmaps and initiatives of all MDAs of Nigeria; studies of cooperate sector and state programmes; assessment of private sector growth requirements that can be improved by knowledge systems and diffusion of STI into society. By its mandate, the Federal Ministry of Science and Technology (FMST) views itself as both an implementer and coordinator of efforts by all stakeholder organizations on improvement of R and D to support Nigeria's sustainable development plans.

At the Interactive Fora with State Commissioners of Science and Technology that I organized as part of my Ministry's stakeholder engagement processes in Abuja and Osun State on December 14th - 15th, 2015, and 2nd - 4th November, 2016 respectively, the Fora identified some constraints to the implementation of Nigeria's Science and Technology Policy of 2012 which would have catalyzed Nigeria's technological/ industrial revolution. The key constraints are as follows: the uptake of R&D results, by industries and SMEs in Nigeria is still very low (about 25% in the food sector); weak linkages and collaboration among key stakeholders in the STI system (knowledge database centres, government and industry, etc.) are barriers to Nigeria's national innovation system; weakness in R&D results, thereby, leading to duplication of efforts; lack of confidence of industries in the ability of Universities to meet their needs; Inadequate funding of research and development; lack of adequate infrastructure as well as weak institutional capacity. This NSTIR 2030 is the strategic response to the needs identified at the fora. It is designed to catalyze effective implementation of programmes and projects that Nigeria's Ministries, Departments and Agencies (MDAs) have included in their roadmaps and plans, most of which are included in various tables in the full Roadmap document. Although, those Roadmap extends to the 2030-time horizon which desirably coincides with the Sustainable Development Goals (SDGs) programme of the United Nations to which

Nigeria subscribes, it also covers the realities of Nigeria's current short-term economic development as contained in the "Nigeria Economic Recovery & Growth Plan 2017 – 2020".

NSTIR 2030 covers three implementation periods: the short term (2017 – 2020), the medium term (2021 – 2025), and the long term (2026 – 2030). Several critical short term programmes and projects have already been initiated, among which are consultations with partners on commercialization of locally invented machines, and formulated chemicals and food products, establishment of science museums, artisan training, and establishment of a science and technology bank to support a National Research and Innovation Fund.

The current Administration's National Economic Recovery Plan (NERP) 2017 – 2020 that has been approved covers programmes and projects that will rapidly boost the economy through job creation, increased productivity in traditional sectors, and diversification of economy through high-impact projects and incentives in new sectors. Some of the projects and programmes include promotion of the beneficiation of solid minerals, support of innovation to improve productivity and competitiveness, rapid development of infrastructure (roads, rail, ports and power) boosting of oil exploration and downstream activities, export of processed agricultural products and manufactured goods, and development of self-sufficiency in food and agro-products. The set of projects and programmes listed above is complemented by others configured by MDAs in such areas as energy systems, health, infrastructure, aviation, education, ICT, environment, water resources and youth employment. NSTIR 2030 programmes and projects are designed to support the effective and efficient implementation of these plans through policy support, infrastructure framing, research and development, training /talent engagement, technology and commercialization support, enhancement of general science literacy/public enlightenment, as well as monitoring and evaluation. Most of these utilities were lacking or inadequate in Nigeria's previous development plans. They are indispensable to cost-effective and efficient implementation of plans.

Although, Nigeria has not reached its potential on the deployment of STI deliverables into projects and programmes, there have been some remarkable improvements within the past few years especially, on the development of new products and materials. Various FMST institutes have collaborated with other organizations to develop machines and components such as cassava pealing machine, flash dryer for cassava flour production, motorized plantain slicer, mineral processing technologies, laterite grinding machine, solar cooker, NASENI ecofriendly smokeless stove, wind turbines, fiber concrete roof tile-making machines, electrohydro brick-making machine, deep water well drilling rig, PRODA porcelain insulator and NABDA biofuel plant, among others.

Several new and essential products that can support import substitution policies when they are commercialized have also been developed by FMST institutes and centers, and their collaborators. Among them are laboratory chemicals, fertilizers, animal feeds, bio-pesticides, sorghum malt, cassava noodles, palm wine, gums, glues and

adhesives, kenaf fiber, Neem antiseptic soap, herbal arthritis ointment, herbal cough syrup, FIIRO bar soap and NARICT biofuel. All the products listed above are ready for commercialization. In consistency with Nigeria's national STI policy which serves as the guide for implementation of NSTIR 2030 activities, FMST is working with stakeholders to move Nigeria's indigenously developed technologies and products to the market place.

NSTIR 2030 targets mobilization of Nigeria's intellectual resources for growth and diversification of the economy, provision of incentives for all stakeholders, including the private sector, academia, Nigeria Diaspora and non-profit/community groups to embrace and engage in STI, improvement of science infrastructure, intensification of research and development, intensification and development of talent and skills, deployment and commercialization of technologies and improvement of science literacy and public stakeholder engagement processes in Nigeria. With implementation of the planned NSTIR 2030 programmes and increased investment in STI, Nigeria is poised to enter the top 20% of technologically advanced countries in the world, with great benefits to industrialization efforts, socio-economic stability and elevation in the quality of life.

These efforts will help move our economy from a resource based to a knowledge based innovation driven economy. The future of our dear country, Nigeria, rests on science and technology. We must efficiently deploy science and technology to effectively utilize our abundant human and material resources for job and wealth creation in order to achieve rapid national development.

Dr. Ogbonnaya Onu,
Honourable Minister of Science and Technology,
Federal Republic of Nigeria.

• Executive Summary

Nigeria is a country that is rife with talent and abundance of natural resources but is yet to achieve its potential in the development and application of science, technology and innovation (STI) effectively in national sustainable development initiatives. The deepest constraint has been non-implementation of effective schemes for propagation of talent and harvesting of the immense intellectual capital of Nigerians which if applied to Nigeria's economic development challenges, would yield innovative systems and products for sustainable economic growth and competitive advantage over other countries. Oil dominates Nigeria's trade, contributing about 90% of total export earnings as crude oil, an unprocessed material that does not contribute significantly to other industrial activities. The Nigerian industrial sector contributes only about 3% of Nigeria's export revenue but gulps overs 50% of Nigeria's imports, thereby ravaging the country's balance of payments. It is well-recognized that there are some constraints to the attainment of Nigeria's comprehensive development plans as well as sector plans, among which are inadequate power supply, limited financing, skilled mismatches and historical social system instabilities.

Nigeria needs to diversify its economy by capitalizing on its huge talent bank and abundance of natural resources. This implies stimulation of productive activities and adoption of export mentality in other economic sectors such as agriculture, low-medium technology manufactured products, pharmaceutics based on local biological resources, processed minerals, and ICT services. Focusing on Nigeria's 2014 Industrial Revolution Plan and many multi-year integrated and sectoral development plans, that targeted intensification of local manufacturing, the primary constraints have been inadequate infrastructure; shortage of skilled manpower; poor linkage to industrial subsectors; over dependence on export of raw materials; the subsistence nature of manufacturing activities without attainment of economy of scale. Inadequate investment in STI to generate new ideas, processes, systems and products that can compete favourably both domestically and in the global market has been a challenge that cuts across all the constraints stated above.

This National Science, Technology and Innovation Roadmap (NSTIR 2030) has been developed after detailed review of Nigeria's challenges and opportunities since independence in 1960 and with fair assessment of future scenarios, to serve as Nigeria's strategic plan for creation and deployment of STI utilities to national development initiatives, programmes and projects. The overall aim is to use STI as the catalyst for Nigeria's long term sustainable development in consistence with the National Policy on Science, Technology and Innovation that was developed in 2011.

The primary objectives of NSTIR 2030 are: to provide a long-term science and technology framework and support mechanisms for industrial revolution in Nigeria; to facilitate the creation and acquisition of knowledge for production, adaptation, replication, and utilization of technologies to support Nigeria's technological and sustainable development aspirations; to support the establishment and strengthening of organizations, institutions, structures and processes for rationalization of decision-making; coordination and management of STI activities within an institutionalized national innovation system; and to encourage and promote the creation of innovative enterprises that can beneficially utilize Nigeria's indigenous knowledge and technologies to produce marketable goods and services that compete with others in the global market. Additional objectives of NSTIR 2030 are to coordinate and support the development of science and technology infrastructure to enable significant research for production of methodologies, models and data to support Nigeria's socio-economic development plans; to devise and implement systems for identification and pruning of STI talent at all ages and educational levels in Nigeria through support and incentives to build a strong long-term workforce; to coordinate the planning and catalyze the implementation of strategic projects such as those of space exploration, advanced computing, telemedicine, robotics advanced navigation systems and, nanomaterials that can accelerate the emergence of Nigeria as a technologically developed country.

NSTIR 2030 congeals the STI elements of past and current national and sectoral roadmaps and plans. Among them are those of Vision 20:2020, the National Economic Empowerment and Development Strategy (NEEDS 2004-2007); 2017 National Economic Recovery and Growth Plan (NERGP); Roadmap for Growth and Development of the Nigerian Mining Industry (2016); the Nigerian Industrial Revolution Plan (2014); the Agriculture Promotion Policy (2016-2020); the National Renewable Energy and Energy Efficiency Policy (NREEP, 2015); the National Health Policy (2016); the National Communication Technology Policy (2012); the Draft National Transport Policy (2010); the Nigerian Water Sector Roadmap (2011); and the Roadmap for the Nigerian Education Sector (2009).

Although NSTIR 2030 is a long-term plan, short-medium term events can generate necessary adjustments in the overall plan while the major targets remain relatively stable. Essentially, short-medium term opportunities to congeal systems toward attainment of NSTIR 2030 will not be ignored. On the other hand, the strategic nature of NSTIR 2030 will aid and factor into the configuration of tactical systems to address short-medium term needs. One of such short-term plans is the National Economic Recovery and Growth Plan (NERGP, 2017-2020) that focuses on the following objectives: macroeconomic policy improvement, economic diversification, competitiveness improvement, social inclusion, and Jobs creation. STI is an enabler of the planning and implementation of the NERGP 2017-2020. Apart from the analytical components such as models, simulations, designs and monitoring systems that can support the first three objectives, science and tech-supported entrepreneurship can generate ventures which when given the right policy framework and financing, can create jobs and promote inclusion. The year 2015 was the sunset of the UN's Millennium Development Goals (MDGs) programme. Nigeria was active in the programme and used it to frame some of its socio-economic development programmes and projects as described in the 2005 report. Its successor programme-the Sustainable Development Goals was initiated in 2015 to cover the period up to 2030 which is incidentally the timeframe for NSTIR 2030 as well. There is then the opportunity for SDG 2030 programmes to overlap beneficially with this plan.

With respect to implementation, NSTIR 2030 is divided into 7 categories of objectives, each of which comprises several initiatives and projects. The 7 categories which align with the Roadmap's objectives are Science Policy Support Programmes and Activities; Science and Technology Improvement; Research and Development Intensification; Training and Talent Deployment; Technology Deployment and Commercialization; and Science Literacy Improvement and Public /Stakeholders Engagement. NSTIR 2030 will be implemented in three time segments, namely: Short Term (2017-2020); Medium Term (2021-2025), and Long Term (2026-2030). NSTIR 2030 covers many high-utility projects that will be implemented by the various institutes/centers of FMST in collaboration with industrial partners, universities, other government entities and NGOs. Examples are commercialization of locally invented equipment and products, establishment of the National Science and Technology Agency/Fund, implementation of artisan training programmes, manufacturing of another set of satellites with expanded involvement of Nigerian scientists and engineers, establishment of advanced analytical laboratories and fabrication of several equipment and their components. Research and development support will be given by FMST units to steel development, automobile production, implementation of renewable energy technologies, telemedicine, local drug manufacture, processing of agricultural products, development and application of new materials in infrastructure and individuals processes, and development and economy-wide applications of ICT techniques, as well as several other STI advancements.

As described in Nigeria's Industrial Revolution Plan published in January, 2014, systems are planned to make industry the dominant job creator and income generator up to 2020. The specific targets are to make Nigeria the preferred manufacturing hub in West Africa; and become the supply source of low-medium-technology consumer and industrial goods domestically, and regionally. The plan which is outlined, covers the creation of 8 general-purpose specialized industrial cities in strategic locations along transport corridors, creation of 6 Technology Innovation Clusters and improvement of services at Nigeria's 27 Free Trade Zones. These facilities will present more opportunities for science- and technology-catalyzed industrialization and create jobs for Nigerians with improvement of the socioeconomic services to Nigeria's growing population which is expected to reach about 289 million by 2030. NSTIR 2030 which has many entrepreneurship elements, will catalyze the production of goods that meet standards specified by international markets in trade agreements.

Budget estimates for the short term programme total ₦180 billion over the three budget years (4-year duration) with the distribution of Programme Configuration and Planning (1.5%), Stakeholder Engagement Processes (2.7%), Management and Personnel Support (11.6%), Facilities and Equipment (25.6%), Deployment and Diffusion of Deliverables (3.4%) and Project Operations (55.2%). NSTIR 2030 will be implemented in collaboration with a wide variety of stakeholders, including academic institutions, public and private research and development centers, the private sector, State and local government agencies, non-profit and community groups, development partners and professional associations using revised and more efficient structures and governance systems that have been ratified by the Federal Government of Nigeria through the Federal Ministry of Science and Technology.

• TABLE OF CONTENTS

A BRIEF ON THE FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY (FMST): STRUCTURE AND OPERATIONS

The Federal Ministry of Science and Technology was established on 1st January, 1980 by Act No.1 of 1980, as the successor organ of Government to the National Science and Technology Development Agency (NSTDA) which was established in 1976. By January 1984, the Ministry was merged with the Federal Ministry of Education and renamed, Federal Ministry of Education, Science and Technology. Almost immediately, (in 1985), the Ministry was re-established.

In its chequered history, the Ministry was again scrapped in 1992 and its research institutes were shared among other Ministries and Agencies including the Federal Ministry of Industry, which was then called the Federal Ministry of Industry Science and Technology, Agriculture, Health and the National Agency for Science and Engineering Infrastructure (NASENI).

Following the need to centrally coordinate R&D activities, the Science & Technology Unit was created in the Presidency in the same year. This Unit later became the nucleus of the Ministry when it was re-established on 26th August 1993. Accordingly, some of its research institutes that were previously transferred to other Ministries, were returned to operate under the purview of the new Federal Ministry of Science and Technology.

The Ministry is currently supervising 17 Research and Development Institutions and interfacing with other cognate Ministries, Departments and Agencies to diversify the economy.

- **MANDATE:** The Federal Ministry of Science and Technology was established to centrally coordinate Research and Development (R&D) activities in Nigeria. It has the following broad mandates.

    - *Formulation, monitoring and review of the National Policy on Science, Technology and Innovation to attain the macro-economic and social objectives of Vision 20:2020 as it relates to science and technology;*
    - *Acquisition and application of science, technology and innovation to increase agricultural and livestock production;*
    - *Increasing energy reliance through sustainable research and development (R&D) in nuclear, renewable and alternative energy sources for peaceful and development purposes;*
    - *Promotion of wealth creation through support to key industrial and manufacturing sectors;*
    - *Creation of technology infrastructure and knowledge base to facilitate its wide application for development;*
    - *Application of natural medicine resources and technologies for health sector development;*
    - *Acquisition and application of space science and technology as a key driver for economic development; and*
    - *Promotion of indigenous research capacity to facilitate technology adaptation, acquisition and transfer.*

- **VISION:** To make Nigeria one of the acknowledged leaders of the scientifically and technologically developed nations of the world.

- **MISSION:** To facilitate the development and deployment of science and technology apparatus to hasten the pace of socio-economic development of the country.

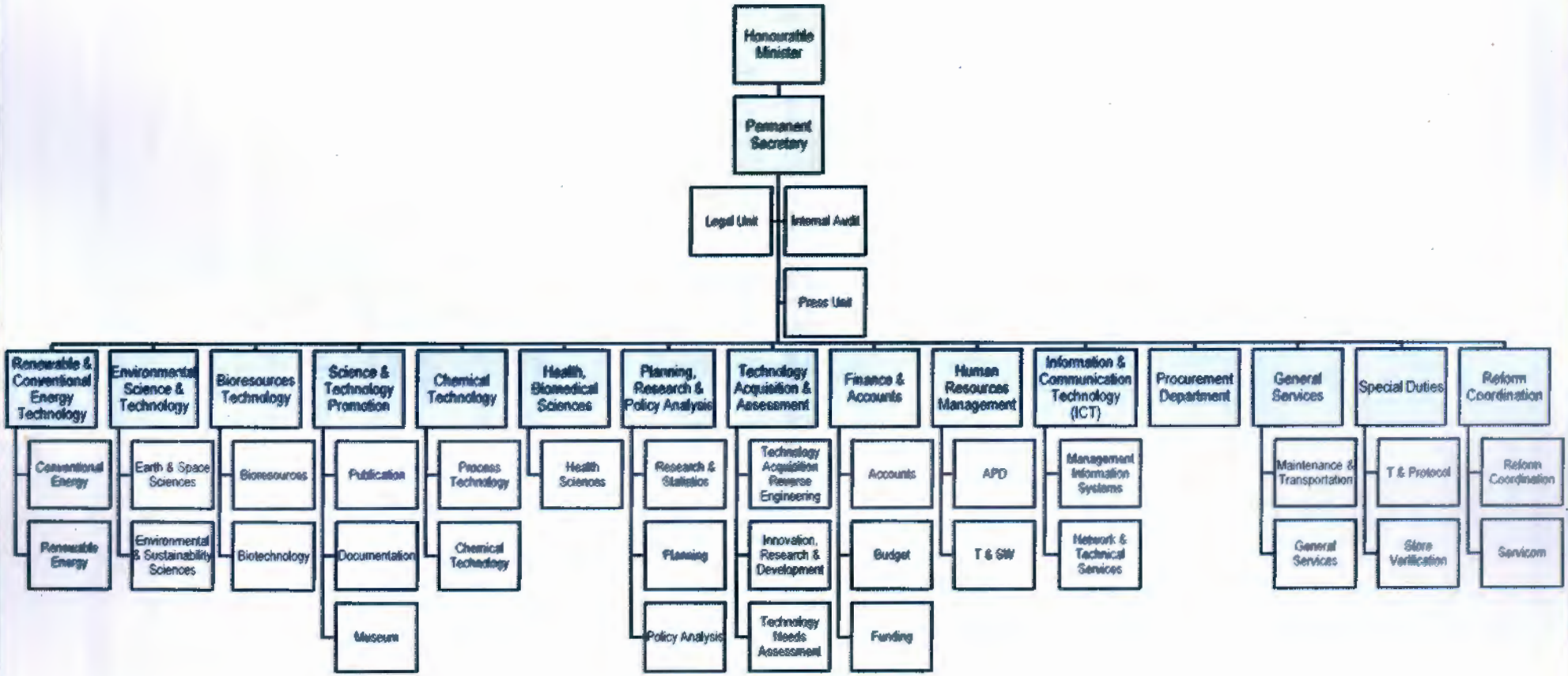
- **STRUCTURE OF FMST:** The Ministry is organized into seven (7) technical and eight (8) service departments. The technical departments are as follows:

  - *Science and Technology Promotion;*
  - *Chemical Technology;*
  - *Bio-resources Technology;*
  - *Health and Bio-Medical Sciences;*
  - *Environmental Science Technology;*
  - *Technology Acquisition and Adaptation;*
  - *Renewable and Conventional Energy Technology*

- **LIST OF PARASTATALS AND COORDINATING DEPARTMENTS OF THE FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY:** The organizational structure provides for effective and efficient supervision and monitoring of activities of the Ministry's Parastatals. There are 17 Parastatals under FMST.

  1. *National Research Institute for Chemical Technology (NARICT), Zaria.*
  2. *National Institute for Leather Science & Technology (NILEST), Zaria.*
  3. *Nigerian Institute of Science Laboratory Technology (NISLT), Ibadan.*
  4. *Federal Institute of industrial Research, Oshodi (FIIRO), Lagos.*
  5. *National Space Research and Development Agency (NASRDA), Abuja.*
  6. *Sheda Science and Technology Complex (SHESTCO), Abuja.*
  7. *Energy Commission of Nigeria (ECN), Abuja.*
  8. *National Office for Technology Acquisition and Promotion (NOTAP), Abuja.*
  9. *National Biotechnology Development Agency (NABDA), Abuja.*
  10. *Raw Materials Research and Development Council (RMRDC), Abuja.*
  11. *National Board for Technology Incubation (NBTI), Abuja.*
  12. *National Agency for Science and Engineering Infrastructure (NASENI), Abuja.*
  13. *Projects Development Institute (PRODA), Enugu.*
  14. *Nigerian Institute for Trypanosomiasis Research (NITR), Kaduna.*
  15. *Nigerian Building and Road Research Institute (NBRRI), Abuja.*
  16. *Nigerian Natural Medicine Development Agency (NNMDA), Lagos.*
  17. *National Centre for Technology Management (NACETEM), Ile-Ife.*

ORGANOGRAM OF THE FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY (FMST)



• Acronyms and Abbreviations

NATIONAL SCIENCE AND TECHNOLOGY IMPROVEMENT ROADMAP (NSTIR) 2030

S/N	ACRONYM ABBREVIATION	DEFINITION
1.	ACRI	Arable Crops Research Institute
2.	AMRG	Advanced Materials Research Group (University of Nigeria, Nsukka)
3.	ARCEDEM	African Regional Centre for Engineering Design and Manufacturing
4.	CAT	Centre for Adaptation of Technology
5.	CBSTE	Centre for Basic Space and Technology Education
6.	CCCES	Center for Climate Change and Environmental Studies
7.	CDRMDS	Centre for Disaster Risk Management and Development Studies (University of Port Harcourt, Port Harcourt)
8.	CERDI	Centre for Energy Research and Development (Ife-Ife)
9.	CERDZ	Centre for Energy Research and Development (Zaria)
10.	CERT	Centre for Energy Research and Training (Ahmadu Bello University, Zaria)
11.	CGG	Centre for Geodesy and Geodynamics
12.	CMRAP	Centre for Malaria Research and Phytomedicine (University of Port Harcourt, Port Harcourt)
13.	CPG	Centre for Petroleum Geosciences (University of Port Harcourt, Port Harcourt)
14.	CRIN	Cocoa Research Institute of Nigeria
15.	CSS	Centre for Space Science
16.	CSTD	Centre for Satellite Technology Development
17.	CSTP	Centre for Space Transport and Propulsion
18.	CWWS	Centre for Wetlands and Waste Management Studies (University of Uyo, Uyo)
19.	ECN	Energy Commission of Nigeria
20.	EMDI	Engineering Materials Development Institute
21.	FIIRO	Federal Institute of Industrial Research
22.	FMST	Federal Ministry of Science and Technology
23.	FRIN	Forestry Research Institute of Nigeria
24.	GERC	Geo-environmental Research Centre Laboratory
25.	HEDEC	Hydraulic Equipment Development Centre
26.	HIIECC	Hilary Inyang Institute of Energy and Climate Change
27.	IAMRAT	Institute for Advanced Medical Research and Training (University of Ilorin, Ilorin)
28.	IAMRT	Institute of Advanced Medical Research and Training (University of Ibadan, Ibadan)
29.	IAMS	Institute of Archaeology and Museum Studies
30.	IAR	Institute for Agricultural Research (Ahmadu Bello University, Zaria)
31.	IART	Institute of Agricultural Research and Training (Obafemi Awolowo University, Ife-Ife)
32.	ICEED	Centre for Energy, Environment and Development
33.	ICEESR	International Centre for Energy and Environmental Sustainability Research
34.	IERD	Institute for Environment Research and Development

35.	IHVN	Institute for Human Virology (Nigeria)
36.	IITA	International Institute of Tropical Agriculture
37.	ILRI	International Livestock Research Institute
38.	IOC	Institute of Oceanography (University of Calabar, Calabar)
39.	ITU	International Telecommunications Union
40.	LCRI	Lake Chad Research Institute
41.	MDAs	Ministries, Departments and Agencies
42.	NABDA	National Biotechnology Development Agency
43.	NACETEM	National Centre for Technology Management
44.	NACGRAB	National Centre for Genetic Resources and Biotechnology
45.	NAFDAC	National Agency for Food And Drug Administration and Control
46.	NAPRI	National Animal Production Research Institute (Ahmadu Bello University, Zaria)
47.	NARICT	National Research Institute for Chemical Technology
48.	NASENI	National Agency for Science and Engineering Infrastructure
49.	NASRDA	National Space Research and Development Agency
50.	NBA	National Biosafety Agency
51.	NBS	National Bureau of Statistics
52.	NBRRI	Nigerian Building and Research Institute
53.	NCAM	National Centre for Agricultural Mechanization
54.	NCDC	Nigerian Centre for Disease Control
55.	NCEE	National Centre for Energy and Environment (University of Benin, Benin City)
56.	NCEEC	National Centre for Energy Efficiency and Conservation (University of Lagos, Akoka)
57.	NCERD	National Centre for Energy Research and Development (University of Nigeria, Nsukka)
58.	NCHRD	National Centre for Hydropower Research and Development (University of Ilorin, Ilorin)
59.	NCMPM	National Centre for Marine Pollution Monitoring (University of Port Harcourt, Port Harcourt)
60.	NCPRD	National Centre for Petroleum Research and Development (Abubakar Tafawa Balewa University, Bauchi)
61.	NCRI	National Cereals Research Institute
62.	NCRS	National Centre for Remote Sensing
63.	NEDDEC	National Engineering Design Development Centre
64.	NEMA	National Emergency Management Agency
65.	NGSA	Nigerian Geological Survey Agency
66.	NICT	National Institute of Construction Technology
67.	NIFFR	National Institute for Freshwater Fisheries Research
68.	NIFOR	Nigerian Institute for Oil Palm Research
69.	NIFST	Nigerian Institute of Food Science and Technology
70.	NIHORT	National Horticultural Research Institute

71.	NIHSA	Nigerian Hydrological Services Agency
72.	NIJ	Nigerian Institute of Journalism
73.	NILEST	National Institute for Leather Science Technology
74.	NIMET	Nigerian Meteorological Agency
75.	NIMG	Nigerian Institute of Mining and Geosciences
76.	NIMR	Nigerian Institute of Medical Research
77.	NIOMR	Nigerian Institute for Oceanography and Marine Research
78.	NIPRD	National Institute of Pharmaceutical Research and Development
79.	NISER	Nigerian Institute of Social and Economic Research
80.	NISLT	Nigerian Institute of Science Laboratory Technology
81.	NITDA	National Information Technology Development Agency
82.	NITR	National Institute for Trypanosomiasis Research
83.	NMC	National Mathematical Centre
84.	NMDC	National Metallurgical Development Centre
85.	NNMDA	Nigerian Natural Medicine Development Agency
86.	NOTAP	National Office of Technology Acquisition and Promotion
87.	NPTI	National Power Training Institute
88.	NRCRI	National Root Crops Research Institute
89.	NSPRI	Nigerian Stored Products Research Institute
90.	NSRMEA	National Steel Raw Materials Exploration Agency
91.	NSTIR	National Science, Technology and Innovation Roadmap
92.	NVRI	National Veterinary Research Institute
93.	NWFCRC	National Weather Forecasting and Climate Change Research Centre (NIMET)
94.	NWRI	National Water Resources Institute
95.	PPP	Public Private Partnership
96.	PRODA	Projects Development Institute
97.	REPTEM	Regional Programme for Technology Management
98.	RMRDC	Raw Materials Research and Development Council
99.	RRIN	Rubber Research Institute of Nigeria
100.	RRIN	Rubber Research Institute of Nigeria
101.	SEDI-E	Scientific Equipment Development Institute (Enugu)
102.	SEDI-M	Scientific Equipment Development Institute (Minna)
103.	SERC	Sokoto Energy Research Centre (Usman Dafodiyo University, Sokoto)
104.	SHESTCO	Sheda Science and Technology Complex
105.	SMEDAN	Small and Medium Enterprises Development Agency of Nigeria
106.	SSAN	Social Sciences Academy of Nigeria
107.	STI	Science, Technology and Innovation
108.	VEI	Vocational Educational Institution

1.0 INTRODUCTION

1.1. Nigeria's Science and Technology Heritage

Science is defined in the Oxford English Dictionary as the study or knowledge of the physical world based on observations and experiments. It should be noted that experiments do not have to be physical. They can be analytical. What is certain is that science requires rationalization of methods to reach the results of experiments. Technology is the application of scientific knowledge for practical purposes. Both science and technology constitute time-honoured ways of doing which have, as most would agree, brought tremendous gains despite some negation, to human existence in all spheres of life: advances in medicine, expansion of human social interactions, ease of travel, knowledge about the universe, albeit with some persistent limitations, and greater capacity to configure shelter and produce food. Neither the definition of science nor that of technology ascribes its monopoly to any religion, global region, race or even social class. The current states of stealth are derivatives of techniques that have been developed and practiced in every global region with contributions to different extents, by all races. Recognition of this circumstance and the scientific heritage of Sub-Saharan Africa in general, and the geographical zone that gave birth to Nigeria in 1960 is essential to the revival and sustainability of confidence in the scientists, technologists and even, the general public, about Nigeria's national capacity to achieve significant advances in science and technology.

As clearly expressed by the Japanese in their Japan Vision 2050 published in April 2005 (15), ***"societies in which only the word like "economy" and "growth" are stressed, are definitely not dignified. It is necessary that we should move toward a world whose groups of individuals will form functional organizations and societies to create an image of Japan as a dignified nation".*** Therein, it is also stated ***"two things are important here: first, a national character that cherishes learning, art, science, and the sensibility to care for nature and human beings; and second, a society formed by individuals molded by that national character".***

It is now believed (29) that much earlier than the period of European invasion of Africa, medical practice was much more advanced in Africa than in Europe. Among the pioneering practices in African regions that subsequently became Nigeria, Egypt and South Africa were the use of kaolin to treat diarrhea; and use of salicylic acid-containing plants that attacked cancer, treated malaria and caused abortion. Among the early medical practices in Africa, some of which have survived to date, were vaccination, autopsy, limb removal, teeth extraction and installation, skin grafting, bone setting, anesthesia, tissue cauterization and caesarian section. The Borgu in the Northern part of Nigeria and the Annangs and Ibibios of the southern part of Nigeria have extensive knowledge of medical plants, as well as their processing techniques to date. Africans in different regions of the continent developed numeration systems about 8000 years ago. In contrast to the decimal (base on 10) which is currently universally, used the Yoruba mathematical system was based on units of 20 and was amenable to subtraction and other operations as described by Zaslavsky (30). There were many astronomers in ancient Africa, particularly, the Dogon people of Mali made numerous observations in astronomy (31). The people of Ancient Ikom in present-day Cross River State of Nigeria also produced an astronomical calendar in ancient times. In August 2009, a group of journalists (38) visited the Stone Circle located at Old Nkrigom in Ikom LGA of Cross River State. This megalithic circle served as a calendar in ancient times and is believed to date back 4000 years. Emeagwali (34) has given a dense summary of the scientific and technological contributions of Africans. Some enslaved Africans arrived in the new world with advanced knowledge of farming. In addition, several crop varieties of African origin were adopted in Asia. Among them were coffee, oil palm, African rice (oryza glabberima), sorghum and fonio (digitaria exilis).

Most settlements and kingdoms that were later confederated to become Nigeria, developed appropriate and large engineering structures that required exacting architectural and structural analyses. In many of the structures built in the Sahelian fringes of Nigeria, cooling by evaporation were utilized. Examples of the architectural expertise of people in the region are the reliques of walled cities of Kano, the Bornu Empire and the Benin Empire. Much later in the 17th Century, Lourenco Pinto, the Portuguese captain who visited Benin noted that ***"Great Benin where the King resides is larger than Lisbon, all the streets are straight as far as the eye can see. The houses are large, especially, that of the king which is richly decorated and has five columns. The City is wealthy and industrious. It is so well governed that theft is unknown and the people lived in such security. The artisans have their places carefully allocated in the squares which are divided up in such a manner that in one square, I counted altogether one hundred and twenty Smith's workshops, all working continuously".*** That is the observation

that Pinto reported back in Portugal. It is the Nigerian heritage in town planning and architecture which has been eclipsed by contemporary circumstances. The grandeur of the Benin Empire has been reported by Ugowe (41).

In addition to the observation quoted in the preceding paragraph, Fred Pearce (54) writes about the walls of Benin City ***"they extend for some 16,000 km in all, in a mosaic of more than 500 interconnected settlement boundaries. They cover 6,500 square km and were dug by the Edo people. In all, they are four times longer than the Great Wall of China, and consumed a hundred times more material than the Great Pyramid of Cheops. They took an estimated 150 million hours of digging to construct, and are perhaps, the largest single archaeological phenomenon on the planet"***. It should be noted that as chronicled by Wesler (53), the Wall was partly destroyed by the British in the invasion of 1897.

Metal working has indexed human technological advancement for centuries. As reported in archaeology (48, 49, 50), the use of iron in smelting and toolmaking in West Africa dates back to 1200 BCE. This implies that it was not copied from outside the continent. The expertise of Nigeria-zone dwellers in metallurgy in ancient times extended from iron to brass, bronze, wax and glass as evident in life-size statues composed of these materials in Benin, Ife and other regions beginning in the 13th century. Smelting of iron has profound implications on the depth of technological engagement of the artisans/engineers of that era. Production of iron from its ore through smelting generates silver, iron, copper and other metals from the same ore, implying that metallurgy was extensive in the industries of that era. It is well-known that Africa was a supplier of gold to other parts of the world trough Trans-Saharan caravans during the medieval times. There is controversy regarding the date of initiation of iron-making in Africa as a whole, due to archaeological finds that are outliers (45). However, it is known that by the time the first Europeans arrived in Africa, iron had been developed in West Africa with legacies that still exist in traditional settings.

Recent radiocarbon dating of Central and Eastern Nigerian artifacts reported in the news (42) indicate the ancient existence of a vibrant Iron Age in the region. Studies by Bernard Fagg enabled the conclusion that Nok Culture site at Taruga which contains iron slags, furnaces, tuyeres, pottery and charcoal is a site that dates back to the first Millennium BC and continued into the first two centuries AD. Recent dating of artifacts from an iron smelting site in Leija in Nsukka LGA of Enugu State performed in Sweden using modern radiocarbon and thermo-luminescence methods, indicate the age of 1445 BC. Thus, the Iron Age was in the region as early as 3445 years ago. This is comparable to or earlier than the Iron Age of other global regions and indicates independent expertise technology in Central and Eastern Nigerian areas in ancient times.

A feature article (35) covers blacksmithing in three Awka Villages in Anambra State of Nigeria (Agulu-Akwa, Amaikwo and Ezi-Awka). This vocation dates back to 1896. Many Nigerian art masterpieces which could only be sculptured with deep knowledge of the science of materials and casting of engineering tools, are found in museums outside Nigeria. Among them is the ivory mask/pendant of **Benin Empire's Queen Idia, 12th**-15th Century Ife metal, terracotta and stone sculptures in foreign museums, and several others that have been chronicled and described (70,71). There are reputed to be as many as 600 pieces of African art in display at the British Museum and hundreds of others in storage at its warehouse in Hackney, North London. Locally, the Igbo Ukwu Museum which is an outpost of **Nigeria's National Commission for Museums and Monuments** (NCMM) in Aguata Local Government Area of Anambra State, contains 1000-year-old artifacts (39) described as ***"unique"*** and displaying ***"a superb level of technical artistry in (of) the Igbo Ukwu forest land"***. In the collection are bronze sculptures discovered by a resident of the area in 1939. The British Secretary of State for the Colonies commissioned mineral surveys of Southern and Northern Nigerian Protectorates in 1903 and 1904 respectively, setting the framework for the beginning of organized mining in Nigeria between 1902 and 1903 (13). Tin ore (cassiterite) was the initial focus by the Royal Niger Company in 1904 followed by gold in 1914 with mines located in Niger and Kogi States. In 1916, coal mining began in Enugu followed three years later by the formation of the Geological Survey of Nigeria.

With respect to leather science and technology, the Hausa regions of Northern Nigeria supplied the Mediterranean markets with much of the leather that was wrongly tagged as Moroccan leather. Sourced from the present-day Northern Nigeria, that leather went as far as Normandy and Britain (46).

Many people are at best, lightly aware of the fact that written communication in Nigeria precedes the arrival of explorers, invaders and missionaries. The Ibibio/Efik of Akwa Ibom State/Cross River State of Southern Nigeria initiated and implemented Nsibidi which is an ideographic suite of symbols that was

the privy knowledge of the Ekpe Secret Society. The Bamun of neighboring Cameroon went further by developing an indigenous writing system. As featured authoritatively in the New African (44), the Bamun Palace in Foumban, Western Cameroun holds about 7000 weathered documents, most of which were written before the first arrival of colonialists in the region in 1902. The documents cover the Bamun history, medicine, religion and magic. Maps and place names all written in the Bamun script, are stored there.

The contributions of the ancient and medieval city states and other jurisdictional entities that later became Nigeria to advances in science and technologies should approximately be viewed within the larger African context. In general, there is little dispute about Ancient Egypt's prominence in the arts, science and technology, buoyed by the fact that evidence, including the pyramids abounds. Unfortunately, as noted by others (43), there is frequent ideological posture by some historians with bearing on the awareness of others, including Africans, to portray ancient Sub-Saharan Africans as those who were uncivilized, barbaric, primitive and defenseless. Essentially, ancient Egypt's accomplishments in philosophy, architecture, science and technology are displaced from black Africans and hung on the Arabs who were the last successful invaders of North Africa. This erasure of heritage has been a mental threat to the self-confidence of modern-day Africans on scientific and technological matters. Nigerians and indeed, African scientific renaissance to which the African Union and many individual African countries have expressed commitment, must begin with correction of distorted history about black African scientific and technological heritage.

Considering the racial composition of the Ancient Egyptians, the Great historian Herodotus, describing the Colclians of the Black Sea shores, presented them as ***"Egyptians by race" with "black skins and kinky hair".*** As noted in another review (67), the Greek philosopher, Apollodorus, also described ancient Egypt as ***"the country of the black-footed ones".*** In a letter sent by the French explorer-Jean-Francois Champollion to his brother Jacques Joseph about the Rosetta Stone which was found in Egypt in 1799 during Napoleon Bonaparte's expedition, it is evident that the ancient Egyptians since at least, the 18th Dysnasty (233BC), recognized their racial composition as Kemmui, Nahasi, Namou and Tahmou, corresponding to Egyptian, Black Africans, Asians and Europeans. Jean-Francois wrote in his letter ***"Thus, we have before our eyes the images of various races known to the Egyptians, established during that early epoch".*** Aristotle, the peerless Greek philosopher wrote also in Physiognomonica, that ***"the Ethiopians and Egyptians are very black".*** The most famous of the several ancient black philosophers who regrettably are unknown to most Africans were Imhotep (2700 BC), Ptahhotep (2414 BC), Kagemni (2300 BC), Merikare (1990 BC), Sehotep-ibra (1991 BC), Amen-emhat (1991 BC), Amenhotep (1400 BC) and Duaf (1340 BC). Many Greek philosophers visited and studied in Africa after being prohibited for about 3000 years. The great libraries of Egypt were looted during Roman control and that circumstance persisted up to Napoleon Bonaparte's invasion in 1798 AD. Among the Greek philosophers who studied in Africa are Thales of Milelus (624-547 BC), Pythagoras (582-500 BC), and Aristotle (385-322 BC). Readers are urged to find out more by reviewing the summaries presented elsewhere (43, 66, 47, 48, 49, 50, 51, 52, 53, 54). Indeed, the venerable historian-Cheikh Anta Diop, writing in the Origin of African Civilization, wrote (67) ***"Ancient Egypt was a Negro civilization. The history of black Africa will remain suspended in the air and cannot be written correctly until Africa historians connect it with the history of Egypt. The African who evades the problem of Egypt is neither modest nor objective, nor unruffled. He is ignorant, cowardly and neurotic. The ancient Egyptians were negroes. The moral of their civilization is to be counted among the assets of the Black world".***

Colonization of socio-political structures that now constitute Nigeria in the 19th century implied reshuffling and reconstitution of all pre-existing systems: religious, political, technological and more by the colonial masters. Engineering in the Western sense was introduced into Nigeria during the colonial period to enhance movement of people and goods, as well as political control of the local population. Public buildings, roads, telegraphy and railways were built without development of local engineering capacity beyond menial assignments. Only a few Nigerians are known to have reached professional status of ***"engineer"*** as late as mid-20th century. Those who did had their preliminary training locally before completing their studies overseas. This continued until the 1960s when local universities and other tertiary institutions started engineering degree programmes and expanded science course offerings. Currently, Nigeria has several professional bodies, most of which are listed in Appendix 4; and at least, 120 registered tertiary institutions, the majority of which offer degree programmes in various fields of science and technology.

The Federal Ministry of Science and Technology now includes about 25 research institutes/centers as parastatals or university-nested organizations in various sectors of the Nigerian economy. Nigeria now awards its highest prize for intellectual contribution-the Nigerian National Order of Merit (NNOM) in fields that include Science and Technology, and the Nigerian Academy of Science which was established in 1977 statutorily, promotes technical (scientific and technological activities); organized lectures and advises the Nigerian Government. However, the support systems for integration of science and technology into governance and socio-economic activities are grossly inadequate in Nigeria. It is a primary detractor from Nigeria's effort to industrialize and compete effectively with other nations to elevate the standard of living of Nigerians. Nigeria's public expenditure on research and development is less than 0.1% of its GNP and there are less than 100 Nigerians per one million of its population in research and development. Clearly, much more needs to be done. Programmes are configured herein, to catch up with some front-running countries by 2030.

In spite of these opportunities, it should be noted that Nigeria is still playing catch-up to many countries, particularly outside Africa on innovation in the modern context in which Western-sourced technologies define each country's wealth, stealth and health. It will remain as such until Nigeria can make significant advances either in introducing indigenous knowledge systems and technologies partially or fully at appropriate scales, or adapts and deploys foreign technologies effectively or does both conveniently. Success in all these regards gains from awareness of the scientific and technological heritage of Nigeria by Nigerians within the overall framework of black African civilization.

1.2. Science and Technology in Decades of Nigeria's Development Planning

The history of development planning in Nigeria has been analyzed by many authors (2, 5, 12, 13, 20, 23, 24, 40, 55, 60, 66, 77, 95). Development planning in Nigeria predates independence in 1960.

• **The 10 year Development Plan (1945-1955):** The first systematic plan was the 10 years development plan (1945-1955) which was formatted by the Colonial Office in London in 1945 and implemented by a central development board. Planning was integrated with central consultations at provincial levels. Nevertheless, the central objective of this plan which subsequently jacketed Nigeria's post-independent development was the development of basic infrastructure to support harvesting of raw materials from Nigeria. It focused on implementation of isolated projects and lacked the programme integration that would have given it the strategic bent that Nigeria would subsequently need as a country. Local talent and research were not developed to support programs.

• **The Second Development Plan of 1955-1960:** This was formatted in a way that empowered the Regions of Nigeria. Each of the three regions: North, East and West, prepared its own plan quite apart from the Federal Development Plan. Under such an arrangement, there were replications of projects and analyses were inadequate. Again, the focus was on a collection of projects rather than strategies that would be driven by a national vision and the target of faring well in international trade for domestic advantages. In his paper presented at the US. National Academy of Sciences, Prof. Hilary Inyang (206) has noted that ***"At that time (pre-independence time), African universities were at the vanguard of diverse indigenous groups that rationalized the need for the independence of their countries on the basis of human right to freedom and self-governance. They were not really deep contributors of data or other forms of information to economic development initiatives and governance of their countries. This circumstances was prevalent in Africa until the late 1950s".***

• **The Post-Independent First National Development Plan (1962-1968):** This was the first plan to incorporate detailed national objectives as the envelop for individual projects. A National Economic Council had been established apriori, in 1958 with the mandate of mobilizing the support of Nigerians for the measures that were needed to improve their quality of life. It was intended to wean Nigeria off external sources of capital and manpower. It is observed that the desirable objectives of that plan was not achieved satisfactorily in critical sectors. As summarized recently (40) in a review of 60 years of development planning in Nigeria, there was 34.6% underfulfillment in education, 63.3% in communication, 42.8% in primary production and 56.3% in health. Among the reasons for that recorded underachievement was dependence on British expertise, continued dependence on foreign capital inflows and skewing of bilateral trade in favour of Britain. Import Substitution Industrialization (ISI) was targeted. Many major infrastructural projects were implemented during this planning era, among them, the Kainji Dam, Ughelli Thermal Plants, Oil Refinery, a development bank and the mint/security company

as noted (23). Most of these infrastructure and systems required deep technical management and scientific investments that were never developed domestically.

In the Second National Development Plan (1970-1974), the Federal Government attempted to address the demerits of ISI by focusing on domestic production of intermediate and capital goods. It was an attempt to create a Nigerian industrial structure buoyed by engagement in agriculture, mining, quarrying and transport. Nigeria also became an oil-producer during this period with the attendant elevation of foreign exchange inflows. During this time, the first effort to coordinate scientific research in Nigeria was made (1970) through the establishment of the Nigerian Council for Science and Technology (NCST). Its mandate was to develop national priorities in research and supervise the implementation of basic and applied research in Nigeria. Other appendages of the NCST were also formed: the Agricultural Research Council and the Industrial Research Council in 1971, followed by the Medical Research Council, and the Natural Science Research Council of Nigeria in 1972 and 1973, respectively. In spite of its appendages, the NCST was a monolith and attracted criticism about its efficiency and productivity. This illustrious plan was undone by Nigeria's lack of qualified technical and managerial personnel in the critical areas. Besides, processes for identification and deployment of leaders in such industries, most of which were overseen by Government, were less than optimal.

Through geological surveys that date back to 1958, iron ore was located in Agbaja, Itakpe and Udi while limestone deposits were found at Jakura, Mfamosin and many other regions of Nigeria. Reasonably large deposits of coal were found in Enugu. The variety that is more appropriate for steelmaking (coke-able coal) was discovered at Lafia. After many partnership agreements with foreign firms and market surveys, a contract was awarded in 1970 to Tiaj Prom Export, a now defunct USSR company, to identify feedstock and determine the quality and quantity of materials for establishment of an integrated iron and steel plant to support Nigeria's technology-based industrialization which targeted the production of 750,000 tonnes/year of steel within the second National Development Plan (1970-1975). The Nigerian Steel Development Authority (NSDA) was established in 1971 within this period with research and supervisory functions. As indicated by Lawal (21), the research would focus on geological surveys, metallurgy and market studies.

The plan was to produce steel in three phases: first, the Ajaokuta Steel Plant would produce the technologically easy-to-produce long products at 1.3 million tonnes/year and subsequently, the flat products at 2.6 million tonnes/year. A third phase of 5.2 million tonnes/year would follow. The Nigerian workforce was not adequately skilled in the technologies of flat steel production at the time. The NSDA which was the only technology-oriented and appropriate outfit to manage steel production in Nigeria, was dissolved in 1979 and their functions transferred to non-technical bureaucrats in the Federal Ministry of Steel (21). The NSDA was replaced by the following individual companies and projects.

- Ajaokuta Steel Project, Ajaokuta
- Delta Steel Company, Ovwian-Aladja
- Jos Steel Rolling Company, Jos
- Katsina Steel Rolling Company, Katsina
- Oshogbo Steel Rolling Company, Oshogbo
- National Iron Ore Mining Company, Itakpe
- National Steel Raw Materials Exploration Agency, Kaduna
- National Metallurgical Development Center, Jos
- Metallurgical Training Institute Onitsha

The National Steel Raw Materials Exploration Agency, National Metallurgical Development Center, and Metallurgical Training Institute were designed for sponsorship by the Federal Government while the rest of the entities were privately owned and operated.

As noted by Lawal (21) and confirmed by Ohimain (93) in a summary, poor management by bureaucrats, including non-payment of the Soviets and other contractors, lack of technical expertise and duplication of roles and sub-projects ravaged the otherwise, good plan to produce and supply steel for Nigeria's technological development. With the bleeding of Nigeria's economy subsequently, partly due to

the national economic hardships derived from the Structural Adjustment Programme of the 1980s, the steel industry ground to a halt in Nigeria.

Nigeria still has more than 3 billion tonnes of proven iron ore reserves (93). However, most of the privately-owned steel companies are rolling mills that need billets from integrated mills. Unfortunately, due to mismanagement and lack of technology deployment, the raw materials from the deposits are not harvested and processed adequately to derive steel production for Nigeria's technological revolution. Only the Delta Steel Company still operates.

• **The Third National Development Plan (1975-1980):** This was basically a continuation of the second NDP and was targeted at policy development and implementation to support the private sector to improve Nigeria's productivity. It was launched at the zenith of Nigeria's oil boom. With the high earnings from oil sales, the Government invested highly in heavy industries. Decisions were not always made on the basis of options analyses but based on military edicts and orders. Private firms had easy access to foreign exchange but focused their investments in industries that are described (23) as light, low-technology consumer industries. These industries were based on imported raw materials and machinery, most of which could not even be maintained with local talent. Again, there was a move away from investment in agro-allied industries that would have sourced raw materials locally.

With recriminations about the effectiveness of NCST, it was segmented into the following independent research institutes and replaced in 1977 by the National Science and Technology Development Agency (NSTDA):

- The Cocoa Research Institute of Nigeria [CRIN], Ibadan
- Federal Institute of Industrial Research Oshodi (FIIRO), Lagos
- The Forestry Research Institute of Nigeria [FRIN), Ibadan
- Hydraulic Equipment Research Institute (HERI), Kano
- Institute for Agriculture Research (IAR), Zaria
- Institute for Agricultural Research and Training IAR&T, Ibadan
- Lake Chad Research Institute (LCRI), Maiduguri
- National Agricultural Extension and Research Liaison Service (NAERLS), Zaria
- National Animal Production Research Institute (NAPRI), Zaria
- National Agency for Science and Engineering Infrastructure (NASENI), Lagos
- Nigerian Building and Road Research Institute (NBRRI), Lagos
- National Cereals Research Institute (NCRI), Badeggi, Niger State
- National Centre for Genetic Research and Biotechnology (NCGRB)
- National Institute for Freshwaters Fisheries Research (NIFFR), New Bussa
- Nigeria Institute for Oil Palm Research (NIFOR), Benin city
- National Horticulture Research Institute (NIHORT), Ibadan
- National Institute for Medical Research NIMR), Yaba
- Nigeria Institute for Oceanography and Marine Research (NIOMR), Lagos
- National Institute for Pharmaceutical Research and Development (NIPRD), Abuja
- Nigeria Institute for Trypanosomiasis Research (NITR), Kaduna
- National Root Crops Research Institute (NRCRI), Umudike, Abia state
- National Research Institute for Chemical Technology (NRICT), Zaria
- Nigerian Stored Products Research Institute (NSPRI), Yaba
- National Veterinary Research Institute (NVRI), Vom, Jos

- Projects Development Institute (PDI), Enugu
- Rubber Research Institute of Nigeria (RRIN), Benin City

These research institutes were not supported to the levels of intellectual and mission-driven productivity that would have enabled them to catalyze Nigeria's emergence as major players in the economic sectors in which they operated. That problem continues till today. Nigeria's lack of adequate capacity for technology development and/or acquisition and lack of specific skills in the sectors on which the Nigerian government established partnership agreements with the private sector caused underachievement of the objectives of the Third National Plan. A full-fledged Federal Ministry of Science and Technology (FMST) was established in 1980. The Research Councils were abolished and their functions integrated into the structure and mandate of the FMST.

• **The Fourth National Development Plan (1981-1985):** This was implemented at a time of global economic recession when Nigeria experienced reduction in foreign exchange earnings, poor balance of payment and growing unemployment. Companies had insufficient foreign exchange to import raw materials and equipment parts. Social conditions, technical inadequacy and economic mismanagement combined to place Nigerians in socio-economic dire straits. The FMST was merged with the Federal Ministry of Education, Science and Technology in 1984 and separated from it in 1985.

The priority areas of the Fourth Plan were agriculture which had been neglected greatly during the oil boom era, education, manpower development, infrastructure, health and housing. However, the problem was ineffective implementation. The Fourth Plan was until then, the worst implemented plan in the history of Nigeria's development planning as evident in the drop of GDP growth to 1.25%. Food was imported in spite of the Green Revolution Programme that was the slogan, and most of the states owed their workers many months of salary. Science and technology was not at any level of deployment that could make any difference. After the official closure of the implementation period of the Fourth Plan, the Structural Adjustment Programme (SAP) was adopted in 1986 as a replacement of previous planning systems. The objectives of the SAP were primarily to promote investment, stimulate non-oil exports, provide support for private sector-led development, promote Nigeria's industrial efficiency, develop/utilize Nigeria's domestic technology with encouragement of the use of local raw materials. The first National Science and Technology Policy was developed in 1986 with equally desirable objectives. The Raw Materials Research and Development Council (RMRDC), the Standards Organization of Nigeria (SON) and other bodies were established by Degree No. 39 in 1987 to support transfer of foreign technology to local firms, license products that meet standards and perform research among other indigenization support roles. Again, the poor results that that Policy attracted were attributable (216, 217) to:

- Independent operation of research institutes without attention to mission and with duplication of efforts.
- Narrow base of S&T research which concentrated on R&D
- Isolation of manufacturing sector from R&D activities and therefore, non-commercialization of ideas.
- Insufficient funding of the S&T sector.

To a large extent, some of these drawbacks are still valid after many subsequent development plans.

• **The Rolling Plans (1990-1992, 1992-1993, 1993-1995, 1997-1999):** The First National Rolling Plan (1990-1992) involved consideration of Nigeria's strategic development needs and the realization that 5-year plans were inadequate with respect for coverage of those needs. The plans were then configured into three tiers as follows.

- A 15-20-year Plan with a clear vision of the terminal state of the economy and coverage of the required policies and actions
- A 3-year National Rolling Plan, and
- A 1-year Annual Budget

The First National Rolling Plan focused on self-sufficiency in food production and raw materials, self-reliant opportunities, enhancement of the socio-political awareness of the people and strengthening of the base for a market-oriented economy. Agricultural development and provision of physical

infrastructure were targeted to reduce economic burden of those who were vulnerable to the ravages of the Structural Adjustment Programme. The deficit was to be financed. The plan lacked the strategic component and was tagged non-scientific by some analysts. Political turbulence was also a factor in its ineffective implementation. The Science and Technology Policy document was revised in 1992 to include S and T infrastructure development and recognition of S&T as input into innovation that is required to drive Nigeria's industrialization and economic development efforts.

Subsequent Plans up to 1999 dealt with reduction of inflation, reduction of the gap between official exchange rate and parallel market rate of the currency, employment creation, rural development, revival and privatization of public assets, expansion of agricultural production and reduction of bottlenecks to industrialization. All of these efforts were still imperiled by inadequate development of a science and technology base, inadequate investment in science and technology, and poor translation of findings of research to commercialization.

Interest in creating and pursuing long-term targets in Nigeria's development effort promoted the creation of Vision 2010 in 1996. *Vision 2010 targeted the transformation of Nigeria into* ***"a united, industrious, caring, God-fearing democratic society, committed to making the basic needs of life affordable for everyone, and creating Africa's leading economy"*** (218). Achievement of this mission was to be through a 15-year perspective plan segmented into multi-tiered medium term plans. Ibietan and Ekhosuehi (218) observe that although this plan relied significantly on attitudinal change by Nigerians, public consciousness was not necessarily raised through engagements to achieve the desired results. Investment in R&D remained flat in spite of international competition on innovation.

• **The National Economic Empowerment and Development Strategy (NEEDS) (2004-2007):** NEEDS focused on medium-term economic development, specifically on wealth creation, employment generation, poverty reduction and values re-orientation. For the latter, a National Orientation Agency which has survived to date, was created. The states were supported to develop similar plans within their jurisdictions. They were called SEEDS. The Local Government's plan was Called LEEDS. Being that NEEDS was focused on socio-economic empowerment, the Federal Government gave emphasis in its budgets to healthcare, education, agriculture, roads, water resources, power and security. This was particularly true of the 2004 and 2005 budgets. The assessment herein, is that NEEDS was reasonably successful but the enormity of Nigeria's development challenges required the sustenance of effort at that level without the ravages of political distractions. Poor investment in innovation continued as a constraint to attainment of socio-economic development targets.

• **Vision 20:2020 (2009-2020):** This was the next focus of Nigeria's medium term socio-economic development effort. When the Vision was developed, it was a long-term plan but three years to go on its expiration, most of the targets are unlikely to be attained within the plan period. In the Vision; Nigeria targeted a status as one of the top 20 economies in the world by 2020. Recently (2015), it ranked 128 out of 141 countries on innovation and ranks 110 out of 141 countries on Industrial Competitiveness Index of UNIDO (2013). The primary objectives of Vision 20:2020 are to guarantee the productivity and well-being of the people; optimize the key sources of economic growth; and foster sustainable social and economic development. A GDP of US$ 900 billion and per capita GDP of US$ 4000 was targeted. As pointed out by Okereke (219), the average per capita income of the top 20 economies in which Nigeria targets inclusion was US$ 100,000 in 2010 as opposed to Nigeria's US$ 1,200 at that time. The part to achievement of Nigeria's target, even at some future date is the use of science and technology as an enabler of its industrialization, education in critical field, peace and security as well as political commitment.

One of the laudable approaches to the configuration and implementation of Vision 20:2020 plans was the creation and convening of a National Technical Working Group (NTWG) on Science, Technology and Innovation which produced its detailed report on global trends, strategies, recommendations and initiatives in 2009 (95). The NTWG analyzed the elements of the Vision and developed recommendations on aspects that need STI advances in the following critical STI sectors into which the FMST has binned its research and associated activities.

- Biotechnology
- Information and Communication Technology
- Space Technology
- Power/Nuclear Energy

- Value-addition to Agricultural and Mineral Resources
- Engineering Infrastructure, Health, Traditional Medicine, Education, Housing, Environment, etc.

The recommendations of the NTWG, most of which were to be implemented before 2020, have been mostly integrated into the NSTIR 2030 because most of the initiatives can no longer be implemented before 2020.

The recommendations of NTWG as the STI elements of Vision 20:2020 was followed by the completion of Nigeria's policy on Science, Technology and Innovation (STI) in 2011 (11). In addition to the following policy objectives, sector plans are also covered. The coverages of this STI policy desirably overlaps with those that have been developed by various Federal Ministries of the Federal Republic of Nigeria, thereby, providing the need for FMST to play the coordinating role.

- Facilitate the acquisition of knowledge to adapt, utilize, replicate and diffuse technologies for the growth of SMEs, agricultural development, food security, power generation and poverty reduction.
- Support the establishment and strengthening of organizations, institutions and structures for effective coordination and management of STI activities within a virile national innovation system.
- Encourage and promote creation of innovative enterprises utilizing Nigeria's indigenous knowledge and technology to produce marketable goods and services.
- Support mechanisms to harness, promote, commercialize and diffuse locally developed
- Technologies for the production of globally competitive goods and service that intensively utilizes Nigeria's raw materials.
- Facilitate and support the creation and maintenance of up-to-date, reliable and accessible database on Nigeria's STI resources and activities.
- Promote activities for effective STI communication and inculcation of STI culture in Nigerians.
- Create and sustain reliable mechanisms for adequate funding of STI activities in Nigeria.
- Initiate, support and strengthen strategic bilateral and multilateral co-operations in scientific, technological and innovation activities across all sectors of the economy.

This NSTIR 2030 serves as an integration framework for various STI plans at the federal and lower jurisdictional levels. Its effective implementation will spur the industrial revolution that Nigeria has unsuccessfully sought since its independence in 1960.

1.3. Perennial Challenges and Circumstances

As shown in Figure 1, sustainable development which has been the target of Nigeria's socio-economic development plans, comprises four cardinal sub-targets: economic development, population management, environmental/natural resources stewardship and social equity. The economic development component is usually the primary target of development plans and initiatives. Population is a significant factor because by necessity, most improvements in socio-economic indices are usually normalized with population and assessed on per capita basis. This includes GDP, disease burden, accident rates and mortality. Environmental stewardship is one of the determinants of quality of life. It impacts on human well-being, health and even, occupational stability. Social equity is factor in peace and stability of any country or lesser political jurisdiction, and a requirement for the implementation of economic development programmes. A country's assets consist of natural resources which are abundant in Nigeria, process and decision support systems which are still challenged but improving in Nigeria, and service and governance systems on which progress is being made since Nigeria's transition to democracy. Nigeria is at low scoring levels in the operational factors of system planning, system analysis, system design, and system maintenance/improvement. Most of the development plans have been much better than their implementation. Science and technology is a major factor in the improvement and harvesting of the asset base as well as implementation of operations.

Figure 2 shows the distribution of poverty in Nigeria as developed by the World Bank (207) using 2010-2013 data. In both graphs, the national poverty levels approximated 60million people but with significant regional disparities. Levels range from about 6million in the Southeast and Southwest to about 20million in the Northwest. Many other socio-economic indices of Nigeria are summarized in Table 1A. Nigeria's high population is a blessing and a challenge. It is a blessing in the sense that it is a large domestic market for goods. It is a challenge to devise socio-economic schemes to provide for such a large population. Gains must reach scales that are significant to make any dent on the large size of need. Within the next 50 years, the global population is expected to double. As one of the fastest growing countries, Nigeria's population is projected to reach 289 million then. By 2025, its population is projected to reach 225 million. The implication is that Nigeria must catalyze innovative to provide for such a large population as China, Indonesia and India have done to various levels of success. Science and technology and its capacity to drive entrepreneurship is the path to Nigeria's socio-economic progress.

It is well-recognized that there are some constraints to the attainment of Nigeria's comprehensive development plans as well as sectoral plans due to several factors. Focusing on the Nigeria Industrial Revolution Plan (24) which was developed in 2014 as the successor to many multi-year national development plans that had industrialization plans, and other plans that focused on intensification of local manufacturing, the developers of the plan alluded the persistent problems, that are stated below.

- Inadequate infrastructure
- Shortage of skilled manpower
- Poor linkage to industrial subsectors
- Over dependence on export of raw materials
- Basic nature of manufacturing activities

Inherent in the constraints outlined above, especially, in shortage of skilled manpower, and overdependence on export of raw materials are neglect of the role of science and technology in building the required technical skills, catalyzing entrepreneurship, and achieving advantages in national productivity and trade as demonstrated by many other countries.

The Nigerian Industrial sector is challenged. It contributes about 3% of Nigeria's export revenue but gulps over 50% of Nigeria's imports, thereby ravaging the country's balance of payments. Oil dominates Nigeria's trade, contributing to about 90% of total export earnings but as crude oil, an unprocessed material that does not contribute significantly to other industrial activities. Nigeria's industrial sector is non-performing as regards its contribution to the national economy and socio-economic growth.

At the National Science and Technology Council Meeting organized by the Ministry of Science and Technology in Abuja on December 14-15, 2015, the Council identified some constraints to the implementation of Nigeria's Science and Technology Policy of 2012 which would have catalyzed Nigeria's technological/industrial revolution. An additional Council meeting held in Osun State, confirmed these needs. The key constraints are as follows.

- The uptake of R&D results by industries and SMEs in Nigeria is still very low (about 25% in the food sector).
- Weak linkages and collaboration among key stakeholders in the STI system (knowledge centers, government and industry, etc.) are barriers to Nigeria's national innovation system
- Weak database of all R&D results, thereby, leading to duplication of the efforts
- Lack of confidence of industries in the ability of universities to meet their needs
- Inadequate funding of research and development
- Lack of adequate infrastructure, weak institutional capacity and poor governance at many Nigerian universities and research institution,
- Poor government policy frameworks that seem insufficient to ensure sustained effort on industry and university/research institute collaboration
- Low numbers of technicians and craftsmen as trade and technical schools are presently de-emphasized

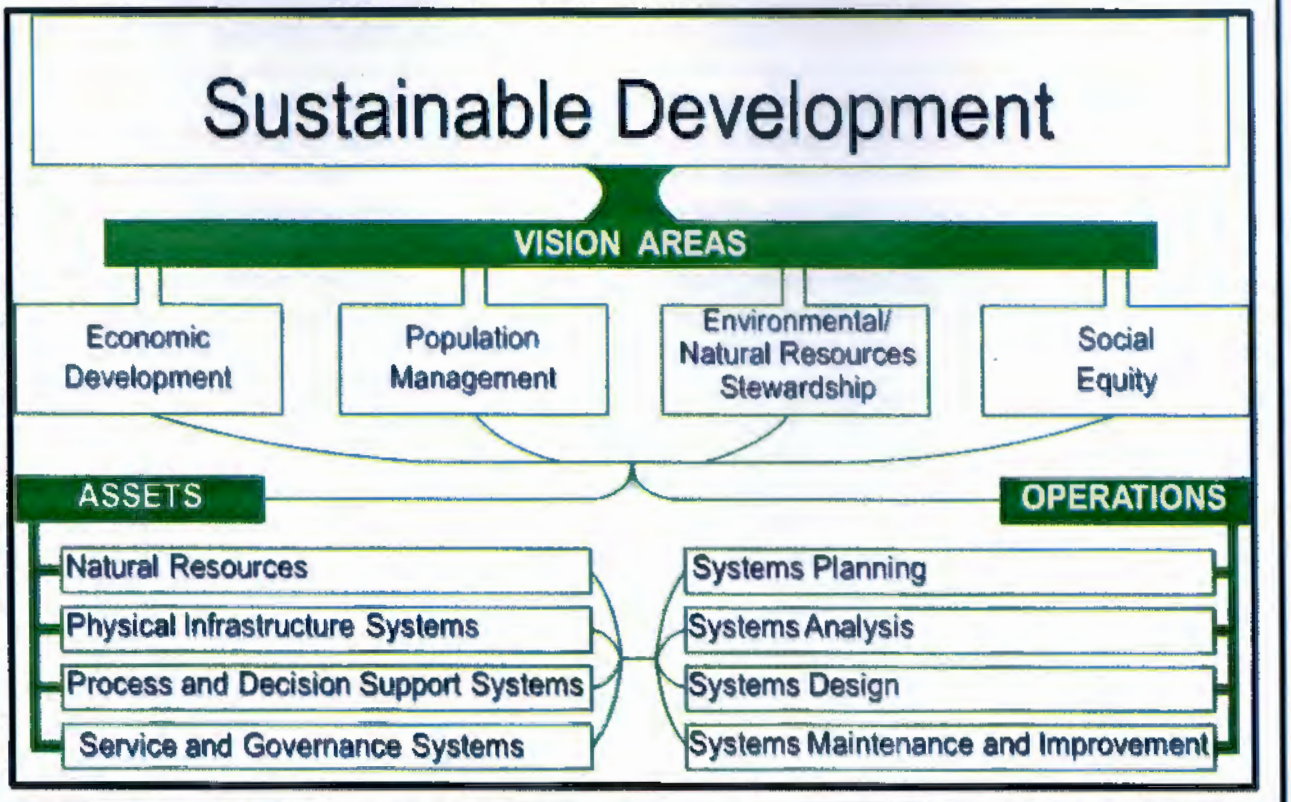
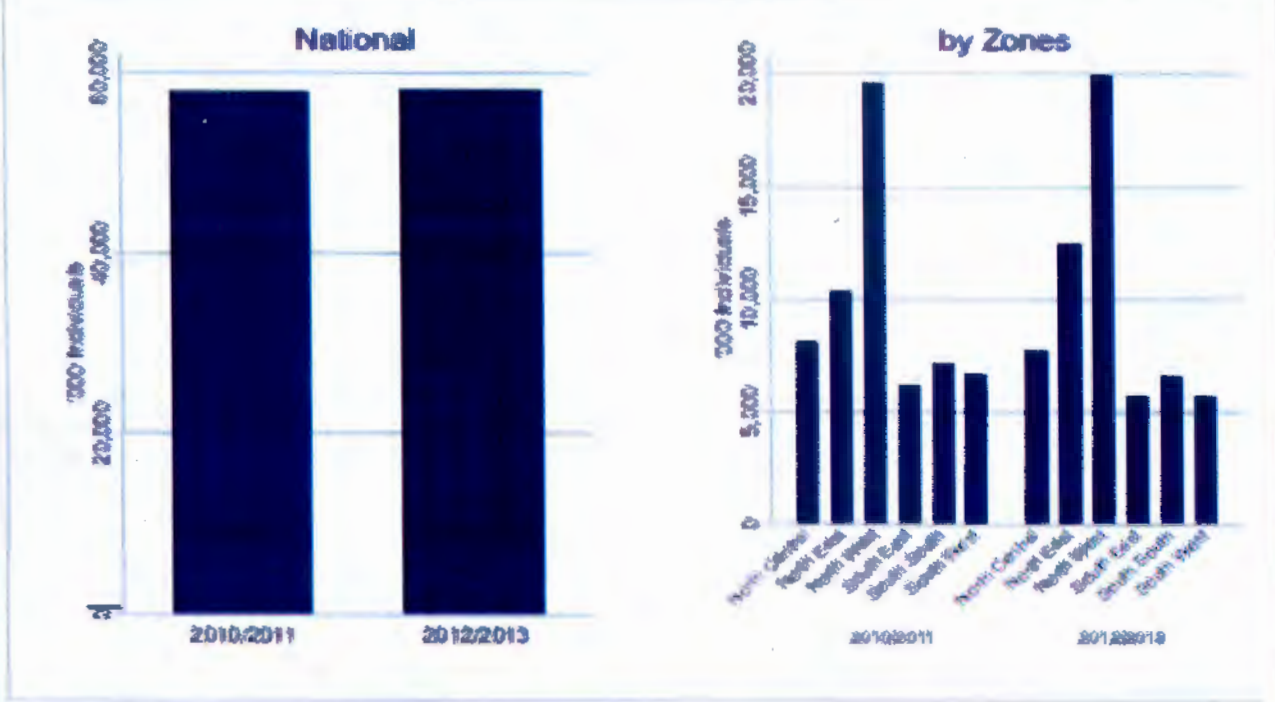


FIGURE 1: CONFIGURATION AND LINKAGES OF SUSTAINABLE DEVELOPMENT SYSTEMS IN THE AREAS OF PLANNING, ANALYSES, DESIGN AND MAINTENANCE (57)



Source: GHS 2010/11-2012/13; post planning and post harvesting visits

Source: World Bank (2014). Nigeria Economic Report

FIGURE 2: NUMBER OF POOR IN THOUSANDS OF INDIVIDUALS (207)

- Poor advocacy among key players and stakeholders in the STI system (knowledge centers, government and industry)
- Apathy for Science, Engineering, Technology and Mathematics (STEM) education in Nigeria
- Most of the R&D inputs of large industries in Nigeria are made by the parent companies with little or no input from research and technologies developed locally
- Lack of patronage of made-in-Nigeria products

The constraints that are listed above have been analyzed and covered by various elements of this NSTIR 2030.

In 2014, Nigeria's GDP growth was rebased and assessed for 2011, 2012 and 2013 at 5.3%, 4.2% and 5.5%, respectively. Non-oil growth reached 8.4% in 2013 but much less growth in agriculture and telecommunications since 2011. As shown in Table 1B while growth increased in manufacturing apart from food manufacturing (plastics, rubber, chemicals and metals), the share of manufacturing in the GDP was still low and remains so. Figure 3 shows the GDP per capita of selected countries plotted from World Bank's 2015 data (207). Nigeria's GDP is reasonably for a country of its socio-economic class when considered in absolute terms but very low when assessed on per capita basis due to its large population.

1.4. Recent Improvements in Plans and Programmes

Although instabilities in the global oil market has recently put Nigeria in precarious economic circumstances, the country has made some progress on the promotion of innovation as a means of growing the economy. Much still remains to be done. In addition to the specific R and D results on innovative methods and products listed in Table 2, research centers and programme units of FMST have made progress on engagement of collaborators, training and dissemination of programme results. Some specific examples drawn from the Ministry's documents (1, 184, 3) are outlined below

- Implementation of the NOTAP-Industry Technology Transfer Fellowship
- Assistance of researchers and traditional medicine practitioners in developing post-harvest process technologies on drying, preservation and storage of Medicinal Aromatic and Pesticide Plants (MAPs) raw materials by NNMDA
- PRODA's technology for production of Electric Porcelain Insulator pin and shackle types which won the National Academy of Science (NAS) prize.
- Completion of R&D activities on High Nutrient Density Biscuit and Drinks that will provide about a third of the dietary allowance for school children
- Establishment of Integrated Cassava Processing Plants at Owode, Yewa, Ondo and Oshogbo.
- Development of prototype science laboratory model by NASENI, NARICT and NISLT to be adopted by secondary schools
- Implementation of the Kano State programme of youth empowerment using science and technology
- NABDA's science advocacy for the passage of the Bio-safety bill
- Advances made by NASRDA on the development of micro-satellite system for environmental monitoring, E-health, E-agriculture, E-commerce and security.
- Publication of two comprehensive volumes of abstracts on Traditional Medicine Knowledge and Practices by NNMDA
- Research progress made by NABDA on the development of DNA finger printing technology
- RMRDC's research breakthrough on the development of water borne paints using paints using poly vinyl acetate (PVAC) and natural rubber latex (NRL) blend as binders.
- Development and production of web offset ink using local raw materials

TABLE 1A: WORLD BANK'S DEVELOPMENT INDICES FOR NIGERIA (1990 – 2016)

Data_Extract_From_World_Development_Indicators Nigeria

Series Name	1990 [YR1990]	2000 [YR2000]	2007 [YR2007]	2009 [YR2009]	2009 [YR2009]	2010 [YR2010]	2011 [YR2011]	2012 [YR2012]	2013 [YR2013]	2014 [YR2014]	2015 [YR2015]	2016 [YR2016]
Population, total	95,617,345.00	122,876,723.00	147,152,502.00	151,115,683.00	155,207,145.00	159,424,742.00	163,770,689.00	168,240,403.00	172,816,517.00	177,475,946.00	182,201,962.00	..
Population growth (annual %)	2.58	2.51	2.64	2.66	2.67	2.68	2.69	2.69	2.68	2.66	2.62	..
Surface area (sq. km)	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	923,770.00	..
Population density (people per sq. km of land area)	104.99	134.92	161.57	165.92	170.41	175.04	179.82	184.72	189.75	194.86	200.07	..
Poverty headcount ratio at national poverty lines (% of population)	..	..	..	..	46.00	..	..	..	..	..	..	..
Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population)	..	..	..	..	53.47	..	..	..	..	..	..	..
GNI, Atlas method (current US$)	27,992,999,737.76	38,427,150,629.07	148,138,901,464.67	174,966,112,689.84	179,702,227,118.35	228,011,978,862.90	281,366,090,071.12	414,843,122,282.59	464,004,984,856.36	526,464,986,890.65	514,027,471,[illegible]	..
GNI per capita, Atlas method (current US$)	290.00	270.00	970.00	1,160.00	1,160.00	1,460.00	1,720.00	2,470.00	2,680.00	2,970.00	2,820.00	..
GNI, PPP (current international $)	169,701,776,245.99	259,603,048,216.16	583,199,170,246.45	630,799,513,624.25	670,068,834,843.56	757,682,456,012.80	809,101,448,266.91	865,788,356,956.18	925,748,154,813.44	1,017,437,744,664.79	1,056,226,961.[illegible]	..
GNI per capita, PPP (current international $)	1,770.00	1,950.00	3,960.00	4,170.00	4,320.00	4,750.00	4,940.00	5,150.00	5,360.00	5,730.00	5,800.00	..
Income share held by lowest 20%	..	..	..	..	5.87	..	..	..	..	..	..	..
Life expectancy at birth, total (years)	46.11	46.62	49.61	50.36	50.87	51.33	51.74	52.11	52.44	52.75	..	..
Fertility rate, total (births per woman)	6.49	6.11	5.93	5.90	5.87	5.84	5.80	5.76	5.71	5.65	..	..
Adolescent fertility rate (births per 1,000 women ages 15-19)	148.61	132.82	123.16	121.95	120.73	119.50	118.29	117.05	114.47	111.90	..	..
Contraceptive prevalence, any methods (% of women ages 15-49)	6.00	..	14.70	14.60	..	..	14.10	13.50	15.10	..	..	..
Births attended by skilled health staff (% of total)	32.00	..	..	38.90	..	..	42.70	..	38.10	..	..	..
Mortality rate, under-5 (per 1,000 live births)	212.50	186.80	146.40	140.90	135.60	130.90	126.50	120.90	116.60	112.50	[illegible]	..
Prevalence of underweight, weight for age (% of children under 5)	36.10	..	25.70	25.70	..	..	24.40	..	21.00	19.80	..	..
Immunization, measles (% of children ages 12-23 months)	54.00	28.00	41.00	53.00	54.00	56.00	49.00	42.00	47.00	51.00	[illegible]	..
Primary completion rate, total (% of relevant age group)	..	..	60.49	69.38	73.32	76.05	..	..	..	..	..	..
Gross enrollment ratio, primary, both sexes (%)	86.26	98.96	92.90	83.76	84.99	84.72	..	..	..	..	..	..
Gross enrollment ratio, secondary, both sexes (%)	24.60	24.46	31.61	36.10	38.90	43.84	..	..	..	..	..	..
School enrollment, primary and secondary (gross), gender parity index (GPI)	0.79	0.82	0.86	0.88	0.90	0.91	..	..	..	..	..	..
Prevalence of HIV, total (% of population ages 15-49)	1.80	3.90	3.70	3.60	3.50	3.50	3.40	3.30	3.20	3.20	[illegible]	..
Forest area (sq. km)	112,340.00	131,370.00	102,698.00	98,402.09	94,606.00	90,410.00	86,214.00	82,218.00	78,122.00	74,026.00	[illegible]	..
Terrestrial and marine protected areas (% of total territorial area)	9.64	10.76	..	..	..	..	..	..	..	11.92	..	..
Annual freshwater withdrawals, total (% of internal resources)	..	..	5.82	..	..	..	..	..	..	5.93	..	..
Improved water source (% of population with access)	39.90	51.80	60.10	61.20	62.30	63.40	64.50	65.50	66.60	67.60	[illegible]	..
Improved sanitation facilities (% of population with access)	38.10	34.00	31.50	31.20	30.80	30.50	30.20	29.90	29.60	29.30	[illegible]	..
Urban population growth (annual %)	5.45	4.06	4.81	4.80	4.77	4.75	4.70	4.64	4.57	4.48	[illegible]	..
Energy use (kg of oil equivalent per capita)	694.66	700.24	747.10	749.22	718.05	752.52	775.04	796.63	773.02	..	..	..
CO2 emissions (metric tons per capita)	0.40	0.64	0.65	0.64	0.49	0.58	0.59	0.59	0.66	..	..	..
Electric power consumption (kWh per capita)	86.71	74.13	138.14	126.53	119.85	135.64	149.31	155.85	141.87	..	..	..
GDP (current US$)	30,757,075,595.37	46,385,996,028.95	166,451,213,395.64	208,064,753,796.47	169,481,317,640.36	369,062,464,570.39	411,743,801,711.64	460,953,836,444.36	514,966,287,206.51	568,498,939,784.02	481,660,[illegible]	..
GDP growth (annual %)	12.77	5.32	6.83	6.27	6.93	7.84	4.89	4.28	5.39	6.31	[illegible]	..
Inflation, GDP deflator (annual %)	9.29	35.23	4.77	10.84	-4.32	100.82	9.51	9.27	5.87	4.65	[illegible]	..
Agriculture, value added (% of GDP)	31.52	26.03	32.71	32.85	37.05	23.89	22.29	22.05	21.00	20.24	[illegible]	..
Industry, value added (% of GDP)	45.27	52.21	40.65	41.48	34.21	25.32	28.35	27.31	26.04	24.96	[illegible]	..
Services, etc., value added (% of GDP)	23.21	21.76	26.63	25.67	28.74	50.79	49.36	50.63	52.97	54.82	[illegible]	..
Exports of goods and services (% of GDP)	36.34	51.73	33.73	39.88	30.77	25.26	31.33	31.44	18.05	18.48	..	..
Imports of goods and services (% of GDP)	17.69	19.65	30.73	25.09	31.03	17.59	21.46	12.94	13.00	12.45	..	..
Gross capital formation (% of GDP)	14.43	7.03	9.26	8.33	12.09	17.29	16.21	14.91	14.90	15.80	..	..
Revenue, excluding grants (% of GDP)	..	..	11.14	12.96	10.47	5.57	5.58	5.00	..	..	..	..
Cash surplus/deficit (% of GDP)	..	..	-0.56	-0.19	-3.21	-1.99	-1.82	-1.34	..	..	..	..
Time required to start a business (days)	..	..	21.60	19.30	19.30	19.30	21.60	21.60	30.50	30.50	[illegible]	..
Domestic credit provided by financial sector (% of GDP)	21.90	10.01	19.20	26.65	37.11	18.80	22.15	20.80	21.85	21.80	..	..
Tax revenue (% of GDP)	..	..	3.98	5.46	5.11	2.27	1.80	1.56	..	..	..	..
Military expenditure (% of GDP)	0.79	0.79	0.58	0.78	0.89	0.54	0.58	0.50	0.47	0.41	[illegible]	..
Mobile cellular subscriptions (per 100 people)	0.00	0.02	27.45	41.66	47.96	54.66	57.96	66.80	73.29	77.84	[illegible]	..
Internet users (per 100 people)	0.00	0.06	6.77	15.86	20.00	24.00	28.43	32.80	38.00	42.68	[illegible]	..
High-technology exports (% of manufactured exports)	..	0.59	1.00	0.41	2.53	1.09	1.20	1.88	2.74	2.10	..	..
Overall trend of statistical capacity (scale 0 - 100)	..	..	60.00	67.78	66.67	68.89	73.33	74.44	72.22	75.22	[illegible]	..
Merchandise trade (% of GDP)	62.50	64.02	60.54	65.47	53.49	34.75	41.77	36.95	30.76	30.12	[illegible]	..
Net barter terms of trade index (2000 = 100)	88.51	100.00	176.62	216.45	154.29	184.19	220.51	226.88	223.76	210.68	..	..
External debt stocks, total (DOD, current US$)	33,858,312,000.00	32,374,086,000.00	12,029,690,000.00	13,027,758,000.00	15,869,813,000.00	15,419,952,000.00	17,416,880,000.00	18,810,320,000.00	21,615,716,000.00	26,958,199,000.00	..	..
Total debt service (% of exports of goods, services and primary income)	22.60	9.76	1.44	9.74	1.24	1.06	0.59	0.41	0.61	0.82	..	..
Net migration	..	..	-900,000.00	..	..	..	..	-300,000.00	..	..	..	..
Personal remittances, received (current US$)	10,009,999.00	1,391,799,577.39	18,011,296,570.16	19,205,913,452.66	18,868,329,379.72	19,744,686,092.98	20,615,891,980.20	20,542,959,359.18	20,797,132,347.20	20,829,179,423.37	20,554,020,[illegible]	..
Foreign direct investment, net inflows (BoP, current US$)	587,862,970.69	1,140,137,859.76	6,035,971,231.03	6,196,606,619.16	8,556,840,768.97	6,026,232,041.28	8,841,112,286.96	7,009,934,204.80	5,562,873,605.74	4,655,849,169.78	3,064,[illegible]	..
Net official development assistance and official aid received (current US$)	266,999,999.99	179,700,000.00	1,956,269,999.99	1,299,160,000.00	1,667,870,000.00	2,067,800,000.00	1,764,650,000.00	1,911,660,000.00	2,516,100,000.00	2,476,180,000.00	..	..

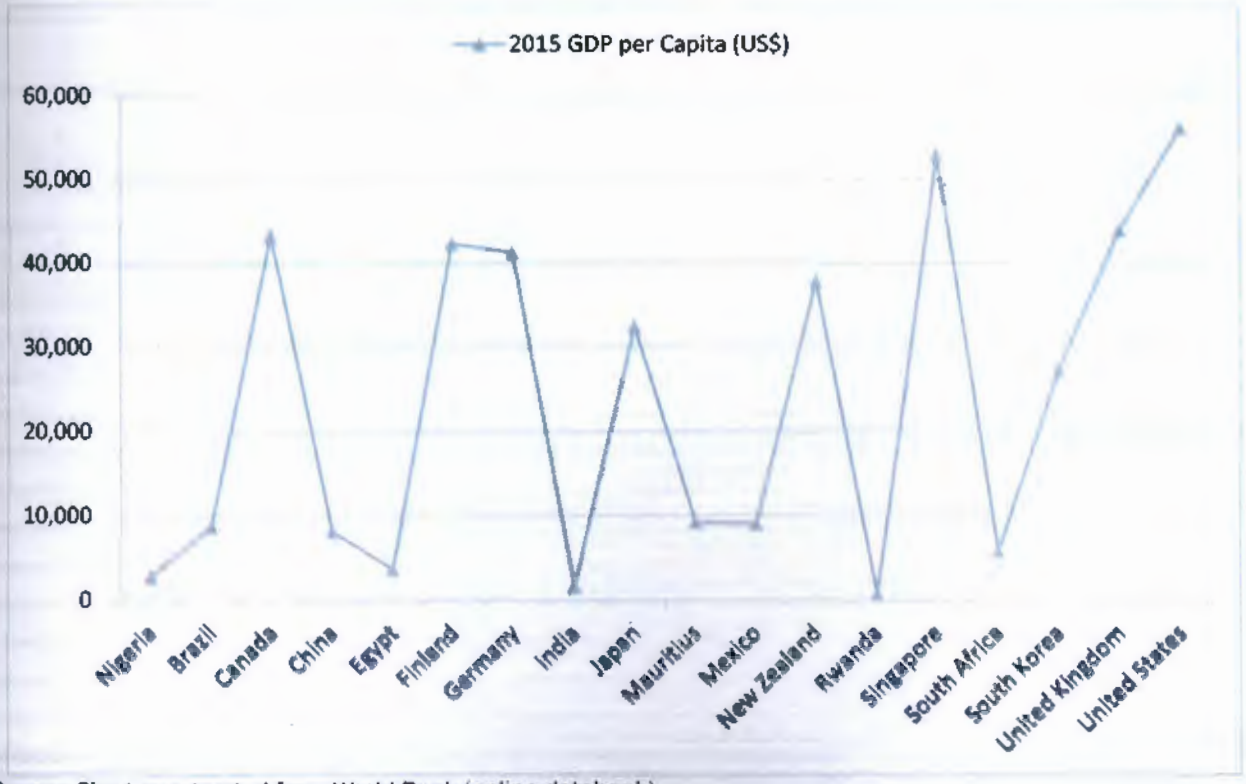
Source: World Bank Online

TABLE 1B: GDP GROWTH IN SELECTED SECTORS OF THE NIGERIAN ECONOMY (58)

A Comparison of Newly Re-Based and Older GDP Estimates	2011	2012	2013
Total	5.3	4.2	5.5
Non-Oil GDP	5.8	5.8	8.4
Agriculture	2.9	6.7	2.9
Crude Oil and Gas	2.3	-4.9	-13.1
Manufacturing	17.8	13.5	21.8
including food, beverages, tobacco	7.3	6.6	11.8
Electricity, Gas, and Utilities	39.5	14.6	14.6
Construction	15.7	9.4	14.2
Trade	7.2	2.2	6.6
Transportation	6.0	-3.4	3.8
Telecommunications and Info Services	1.2	3.7	4.7
Entertainment, Broadcasting, Movies, Music	10.5	1.9	24.1
Real Estate	0.4	5.6	12.0

Source: ABS

Source: World Bank (2014). Nigeria Economic Report



Source: Chart constructed from World Bank (online databank)

FIGURE 3: 2015 GDP PER CAPITA (US$) FOR SELECTED COUNTRIES.

TABLE 2: COMMERCIALIZATION-READY PRODUCTS OF NIGERIA'S RESEARCH AND DEVELOPMENT ORGANIZATIONS KEY INDUSTRIAL SECTORS (LIMITED TO CRITICAL ITEMS)

NARICT.....National Research Institute for Chemical Technology	NASENI.....National Agency for Science and Engineering Infrastructure
RMRDC.....Raw Materials Research and Development Council	NILEST.....Nigerian Institute of Leather Science and Technology
NASRDA.....National Space Research and Development Agency	NNMDA.....Nigerian Natural Medicine Development Agency
NITR.....National Institute for Trypanosomiasis Research	NOTAP.....National Office of Technology Acquisition and Promotion
SHESTCO.....Sheda Science and Technology Complex	FIIRO.....Federal Institute of Industrial Research, Oshodi
NBRRI.....Nigerian Building and Research Institute	NABDA.....National Biotechnology Development Agency
ECN.....Energy Commission of Nigeria	PRODA.....Projects Development Institute

INDUSTRIAL SECTOR	PRODUCT		PRODUCER	STATUS	
				PENDING PATENT	READY FOR COMMERCIAL -IZATION
A. AGRICULTURE AND AGRO-ALLIED SECTOR	A.1	Pesticides	NARICT		X
	A.2	Fertilizers	NARICT		X
	A.3	Animal Feeds	NARICT		X
	A.4	Bio-organic Fertilizer	NABDA		X
	A.5	Temporary Immersion Bioreactor System	NABDA/ SHESTCO		X
	A.6	Flash Dryer for Cassava Flour Production	RMRDC		X
	A.7	Organic Fertilizer from Palm Kernel Waste	RMRDC		X
	A.8	Slow-release Nitrogen Fertilizer for Urea	SHESTCO		X
	A.9	Stabilized Plant Growth Hormone and Organic Fertilizer from Moringa Olefeira	SHESTCO		X
	A.10	Neem Oil	NARICT		X
	A.11	Neem Bio pesticide	NARICT		X
	A.12	Azadiracthin (export grade)	NARICT		X
	A.13	Hydrated Lime	NARICT		X
	A.14	Fruit Juice	NABDA		X
	A.15	Sorghum Malt	FIIRO		X
	A.16	Carbonated Fruit Juice	FIIRO		X
	A.17	Tomato Paste/Ketchup	FIIRO		X
	A.18	Edible Mushrooms and Spawns	FIIRO		X
	A.19	Cassava Noodles	FIIRO		X
	A.20	Moringa Oil Food Supplement	RMRDC		X
	A.21	Cassava Peeling Machine	FIIRO		X
	A.22	Motorized Plantain Slicer	FIIRO		X
	A.23	Manual Ginger Slicer	FIIRO		X
	A.24	Cassava Pelletizer	FIIRO		X
	A.25	Flavour for Palm wine	FIIRO	X	
	A.26	Simulated Palm wine	FIIRO	X	
	A.27	various Food-Cutting Devices	FIIRO		X

	A.28	Cassava Pettelizer and Juice Extractor	FIIRO		X
	A.29	Mango Chip Dryer	RMRDC		X
B. MANUFACTURING SECTOR	B.1	Processed Hydrated Lime	NARICT		X
	B.2	Industrial Chemical Products	NARICT		X
	B.3	Leather and Leather Goods	NARICT		X
	B.4	Footwear Designs (Products)	CHELTECH		X
	B.5	Bagaruwa Processing Machine	NASENI		X
	B.6	PRODA School Pencil	PRODA		X
	B.7	FIIRO Bar Soap	FIIRO		X
	B.8	Gums, Glues and Adhesives	FIIRO		X
	B.9	Neem Antiseptic Soap	FIIRO		X
	B.10	Kenaf Fiber	FIIRO		X
	B.11	Silk	RMRDC		X
	B.12	Essential Oil Processing Plant	RMRDC		X
	B.13	Glacier Putty	RMRDC		X
	B.14	Calcinated Kaolin for Paints	RMRDC		X
	B.15	Industrial Thaumatin Production System	RMRDC		X
	B.16	Cellulose from Agric Wastes	RMRDC		X
	B.17	Fabricated Spray Driers	RMRDC		X
	B.18	Laboratory Chemicals	RMRDC		X
	B.19	Aloe Vera Gel	RMRDC	X	X
	B.20	Technologies for Processing Kaslinite, Baryte, Phosphate, Talc and Soda Ash	RMRDC		X
	B.21	Natural Rubber Reinforced with Spent Plastics	RMRDC		X
	B.22	Alkyd Resin using Rubber Seed	RMRDC		X
	B.23	PRODA Porcelain Insulator	PRODA		X
	B.24	Small-scale Salt Processing Plant	RMRDC		X
	B.25	Sawdust Burner	FIIRO	X	
C. MINING SECTOR	C.1	Technologies for Processing Minerals-Kaolin, Baryte, Phosphates, Talc and Soda Ash	RMRDC		X
	C.2	Laterite Grinding Machine	NBRRI		X
D. ENERGY (POWER) SECTOR	D.1	NARICT Biofuel	NARICT		X
	D.2	Biogas from Organic Waste	NABDA		X
	D.3	NASENI Ecofriendly Smokeless Stove	NASENI		X
	D.4	Small-scale Hydropower Plant	ECN		X
	D.5	Improved Woodstove	ECN		X
	D.6	Solar Home System	ECN		X
	D.7	Solar Cookers	ECN		X
	D.8	Solar Dryers	ECN		X
	D.9	Solar Water Heater	ECN		X
	D.10	Solar Still	ECN		X
	D.11	Solar PV Application	ECN		X
	D.12	Biogas Digesters	ECN		X
	D.13	Wind Turbine	ECN		X
	D.14	NABDA Biofuel Plant	NABDA		X
	D.15	NASENI Hydropower	NASENI		X

	D.16	FIIRO Biofertilizer	FIIRO		X
	D.17	Wind Pump for Energy Generation	HEDI of NASENI		X
E. OIL AND GAS SECTOR		None			
F. CIVIL INFRASTRUCTURE SECTOR	F.1	Briquettes Production System	NBRRI		X
	F.2	8-Mould Brick Making Machine	NBRRI		X
	F.3	Manual Brick Making Machine	NBRRI		X
	F.4	Electrohydraulic Brick Making Machine	NBRRI		X
	F.5	Interlocking Brick Making Machine	NBRRI		X
	F.6	Laterite Grinding Machine	NBRRI		X
	F.7	Laterite Mixing Machine	NBRRI		X
	F.8	Manual Paving Stone Machine	NBRRI		X
	F.9	Pedestrian Roller Compactor	NBRRI		X
	F.10	Fiber Concrete Roofing Tile-Making Machine	NBRRI		X
	F.11	Clay Roofing Tile-Making Machine	NBRRI		X
	F.12	Motorized Briquetting Machine for Wood and Agricultural Wastes	RMRDC		X
G. INFORMATION & COMMUNICATION TECHNOLOGY (ICT)	G.1	Barcode of Lite for Generic Mapping	NABDA		X
	G.2	Natural Rubber Reinforced with Plastics	RMRDC		X
	G.3	High Resolution Satellite-NigeriaSat-2	NASRDA		X
H. ENVIRONMENT, WATER AND HEALTH SECTOR	H.1	Pesticides	NARICT		X
	H.2	Tissue Culture Techniques	NABDA		X
	H.3	Digitized Tse-Tse Fly Distribution Mapping System	NITR		X
	H.4	ECOSAN-Ecological Sanitation System	NABDA		X
	H.5	Neem Antiseptic Soap	FIIRO		X
	H.6	NASENI Primary School Science Kits	NASENI		X
	H.7	NASENI Secondary School Science Kits	NASENI		X
	H.8	Deep Waterwell Drilling Rig	NASENI		X
	H.9	Herbal Arthritis Ointment	NNMDA		X
	H.10	Herbal Cough Syrup	NNMDA		X
	H.11	Herbal Mosquitoes Repellent	NNMDA		X
	H.12	Silicon Centrifugation System for Blood Parasites	NITR		X
	H.13	Tse-Tse Fly NITTSE Traps	NITR		X
	H.14	NARICT Insecticides	NARICT		X
	H.15	Malaria and Hepatitis B and C Rapid Diagnostic Kits	NABDA		X
	H.16	Special Traps for Black Flies	NITR		X
	H.17	Glossina Mass Production System	NITR		X

- Development of brake pad from palm kernel shell
- Niger State's energy-efficient wood stove project completion

In addition to the accomplishments of FMST initiatives and collaborative (with FMST centers) projects listed above, there have also been other advances at laboratories operated by other public agencies, the private sector, academic institutions and science and technology initiatives operated by the same categories of organizations. The challenge now is to increase the scale and intensity of such research, development and entrepreneurship support organizations to the extent that can make positive impacts on Nigeria's productivity, GDP growth and the quality of life of its citizens. This is the target of Nigeria's NSTIR 2030 Roadmap.

Recently, PWC (215) developed and published economic growth projections for 32 of the largest economies in the world. They collectively account for 84% of the global GDP. It is projected that the average growth rate will be just in excess of 3% per year for the period 2014-2050. Global economic power shift is expected to continue from the established economies of North America, Western Europe and Japan for the next 35 years. By 2030, two important emerging economies: Mexico and Indonesia will beat UK and France as regards their economic powers expressed in purchasing power parity (PPP) terms. Nigeria and Vietnam are expected to be the fastest growing large economies over the analysis period up to 2050. Table 3A shows the projections for each of the 32 countries. Therein, Nigeria's GDP projected rank rises from 20 in 2014 through 16 in 2030 is the sunset of this NSTIR 2030. Implementation of the policies, programmes and projects described in this document will advance Nigeria to achievement of the ranks projected by PWC.

1.5. Opportunities and Benefits of Science and Tech Improvement and Deployment in Nigeria

Although NSTIR 2030 is a long-term plan, short-medium term events can generate necessary adjustments in overall plan while the major targets remain relatively stable. Essentially, short-medium term opportunities to congeal systems toward attainment of NSTIR 2030 will not be ignored. On the other hand, the strategic nature of NSTIR 2030 will aid and factor into the configuration of tactical systems to address short-medium term needs. One of such short-term plans is the National Economic Recovery and Growth Plan (NERGP) that focuses on the following objectives:

- Macroeconomic policy improvement
- Economic diversification
- Competitiveness improvement
- Social inclusion
- Jobs creation
- Education
- Science, technology and innovation

Science and technology is an enabler of the planning and implementation of the NERGP 2017-2020. Apart from the analytical components such as models, simulations, designs and monitoring systems that can support the first three objectives, science and tech-supported entrepreneurship can generate ventures which when given the right policy framework and financing, can generate jobs and promote inclusion.

2015 was the sunset of the Millennium Development Goals (MDGs) programme that was initiated by the United Nations. Nigeria was active in the programme and used it to frame some of its socio-economic development projects as described in the 2005 report (56). Its successor programme-the Sustainable Development Goals was initiated in 2015 to cover the period up to 2030 which is incidentally, the timeframe for NSTIR 2030 as well. There is then the opportunity for SDG 2030 programmes to overlap beneficially with this plan.

As described in Nigeria's Industrial Revolution Plan published in January, 2014 (24), systems are planned to make industry the dominant job creator and income generator up to 2020. The specific targets are to make Nigeria the preferred manufacturing hub in West Africa; become one of the top 2 manufacturing hubs in West Africa; and become the source for supply of low-medium-technology consumer and industrial goods domestically, and regionally. The plan which is outlined in Appendix 1,

covers the creation of 8 general-purpose Specialized Industrial Cities in strategic locations along transport alignments, creation of 6 Technology Innovation Clusters and improvement of services at 27 Free Trade Zones. These facilities will present more opportunities for science-and technology-catalyzed industrialization and create jobs for Nigerians. NSTIR 2030 which has many entrepreneurship elements, can catalyze the production of goods that meet the standards specified by international markets in trade agreements. An example is the African Growth and Opportunity Act (AGOA) of the United States. The benefit would be an increase in the quantity and quality of exports to the United States under the AGOA agreement. AGOA provides duty-free import quotas on about 6,400 products to merchants from eligible countries.

Nigeria has a large youth population, presently estimated by UNIDO at about 68 million. About 41.6% of young people are unemployed, and it is estimated that 4.5 million people enter the job market annually while absorption is only 10%. Science and technology can be deployed on a more intense level to create knowledge-based industries across many economic sectors to absorb youth. Approaches to doing this have been detailed in this NSTIR 2030. As an example of the S and T-based job training and support system with respect to reduction in unemployment, the quadruple partnership of UNIDO, Industrial Training Fund (ITF), SMEDAN and the Federal Government's National Industrial Skills Development Programme (NISDP) targets the provision of Industry-driven training to Nigerian youth on various trades. The current subsectors and product categories of Nigeria's manufacturing systems are presented in Table 3B. The industrial sectors and the items listed provide guidance to Nigerian manufacturers for engagement as well as serving as targets for training of Nigerian artisans and other industrial support personnel.

Another programme-the UNIDO-HP LIFE Entrepreneurship programme which has been implemented since 2008 through partnership with Hewlett Packard (HP), provides training to students aspiring entrepreneurs and small business owners on the use of IT to create and grow their businesses. A survey was conducted on about 23,571 students (220) to gage the performance of the LIFE programme. The following results were obtained.

- 675 had started their own businesses
- 5197 found jobs in their field of choice
- 355 are presently employed
- 159 new enterprises have been created
- 505 additional jobs were created as a result of the enterprises created by the programme's graduates.

Nigeria's ICT infrastructure is growing. Analyses by Adamu (19) indicate that as at 2013, the opportunities and challenges were as follows

- More than 30,000 km of inter-city fibers already laid
- High volume of unutilized capacity due to duplications
- Vertical transmission gaps
- High cost for end uses
- Mobile broadband operations were launched in some cities.

The opportunities can be exploited and challenges addressed to expand this critical sector of socio-economic development to spur industrial activities and create jobs.

Nigeria has abundant natural: petroleum, gas, solid mineral resources and a wide variety of crops and other economic plants. The sea is open on a coastline that extends for about 852 km along the Atlantic shores in the Gulf of Guinea, covering a maritime area of about 46,000 square km. Marine resources can be exploited and harvested using innovative techniques that science and technology can support. Among the sectors that can benefit from this engagement during the next 5 years are fisheries, aquaculture, wave energy systems, tourism/hospitality, energy systems (harvesting of energy from waves and tides) mining, oil extraction from the deep sea, shipbuilding and marine transportation. New jobs can be created through expansion of opportunities in these sectors with the application of science and technology.

It is common knowledge that utilization of steel has indexed industrial development of many technologically advanced countries in the last one hundred years. Nigeria's quest for industrialization

must by necessity, involve the mining of iron and production of steel in large quantities and internationally competitive costs. All the raw materials required to make steel are available in Nigeria as noted by many analysts (93, 21). The primary resources needed are iron ore, coal, natural gas, and limestone. As early as 1958, Nigeria started its efforts on the development of a vibrant steel industry. However, mismanagement and lack of sustained technical expertise and systems to utilize the products in the production of goods ravaged Nigeria's efforts. Recent efforts to revive steel-making plants in Nigeria will provide this critical material to support tool fabrication, construction and vessels production. Particularly, heavy industries that steel can support would reduce unemployment and build a stable technological base for Nigeria.

As shown in Figure 4A, implementation of the recently developed Nigerian Industrial Revolution Plan (NIRP) requires input of advances (plans, methods, and projects) from several sectors of the Nigerian economy. In the illustration shown in Figure 4A, science and technology features as a primary component of the industrialization plan of Nigeria. NSTIR 2030 is designed as the mechanisms and a set of initiatives and projects that will be input as the scientific and technological contribution into NIRP to enable its effective implementation. Figure 4B shows and effective interaction of STI processes that can create knowledge and physical assets to accelerate systems towards attainment of industrial revolution in Nigeria.

TABLE 3A: CURRENT AND PROJECTED GDP RANKINGS OF COUNTRIES UP TO THE YEAR 2050 (215)

	2014		2030		2050	
PPP rank	*Country*	*GDP at PPP (2014 US$bn)*	*Country*	*Projected GDP at PPP (2014 US$bn)*	*Country*	*Projected GDP at PPP (2014 US$bn)*
1	China	17,632	China	36,112	China	61,079
2	United States	17,416	United States	25,451	India	42,205
3	India	7,277	India	17,138	United States	41,384
4	Japan	4,788	Japan	6,006	Indonesia	12,210
5	Germany	3,621	Indonesia	5,486	Brazil	9,164
6	Russia	3,559	Brazil	4,996	Mexico	8,014
7	Brazil	3,073	Russia	4,854	Japan	7,914
8	France	2,587	Germany	4,590	Russia	7,575
9	Indonesia	2,554	Mexico	3,985	Nigeria	7,345
10	United Kingdom	2,435	United Kingdom	3,586	Germany	6,338
11	Mexico	2,143	France	3,418	United Kingdom	5,744
12	Italy	2,066	Saudi Arabia	3,212	Saudi Arabia	5,488
13	South Korea	1,790	South Korea	2,818	France	5,207
14	Saudi Arabia	1,652	Turkey	2,714	Turkey	5,102
15	Canada	1,579	Italy	2,591	Pakistan	4,253
16	Spain	1,534	Nigeria	2,566	Egypt	4,239
17	Turkey	1,512	Canada	2,219	South Korea	4,142
18	Iran	1,284	Spain	2,175	Italy	3,617
19	Australia	1,100	Iran	1,914	Canada	3,583
20	Nigeria	1,058	Egypt	1,854	Philippines	3,516
21	Thailand	990	Thailand	1,847	Thailand	3,510
22	Egypt	945	Pakistan	1,832	Vietnam	3,430
23	Poland	941	Australia	1,707	Bangladesh	3,367
24	Argentina	927	Malaysia	1,554	Malaysia	3,327
25	Pakistan	884	Poland	1,515	Iran	3,224
26	Netherlands	798	Philippines	1,508	Spain	3,099
27	Malaysia	747	Argentina	1,362	South Africa	3,026
28	Philippines	695	Vietnam	1,313	Australia	2,903
29	South Africa	683	Bangladesh	1,291	Colombia	2,785
30	Colombia	642	Colombia	1,255	Argentina	2,455
31	Bangladesh	536	South Africa	1,249	Poland	2,422
32	Vietnam	509	Netherlands	1,066	Netherlands	1,581

Source: IMF WEO database (October 2014) for 2014 estimates. PwC projections for 2030 and 2050

TABLE 3B: SUB-SECTORS AND PRODUCT CATEGORIES OF NIGERIAN MANUFACTURING SYSTEMS (24)

A. FOOD, BEVERAGES & TOBACCO	
• Beer • Starch and other Miscellaneous Food Products • Flavouring • Soft Drinks and Carbonated Water • Flour and Grain Milling • Meat and fish products • Tea, Coffee and other Beverages • Dairy Products • Fruit Juices	• Tobacco • Biscuits and Bakery Products • Animal Feeds • Poultry • Sugar • Distillery and Blending of Spirit • Cocoa, Chocolate and Sugar Confectionery • Vegetable & Edible Oil • Palm Oil and Palm Oil Products • Rice Processing
B. CHEMICAL AND PHARMACEUTICALS	
• Medical and Special Gases • Soap and Detergent • Petrochemicals, Plastics • Agro-Chemicals (Fertilizers and Pesticides) • Pharmaceutical, Safety Matches, Domestic Insecticide and Aerosol	• Dry Cell Battery, Petroleum Refineries, Gramophone Records and Musical Tapes, Candle, Printing Ink, Toiletries and Cosmetics • Ball Point Pen, Basic Industrial Chemicals, Automotive Battery • Paints, Vanishes and Allied Products
C. BASIC METAL, IRON AND STEEL AND FABRICATED METAL PRODUCTS	
• Steel Pipe • Metal Packaging • Foundry • Metal Manufacturers and Fabricators • Primary Aluminum Producers	• Enamel Wares • Welding Electrode • Galvanized Iron Sheets • Nail and Wires • Steel
D. NON-METALLIC MINERAL PRODUCTS	
• Glass • Ceramics • Asbestos	• School Chalks & Crayons • Cement
E. ELECTRICAL & ELECTRONICS	
• Electronics • Refrigerators & Air conditioning/ Domestic Appliances	• Electric Bulb Lamps, Accessories & Fittings • Electrical Power Control & Distribution Equipment • Cable and Wire
F. TEXTILES, WEARING APPAREL, CARPET, LEATHER/ LEATHER FOOTWEAR	
• Textile & Wearing Apparel • Leather Products • Carpet and Rug	• Footwear • Cordage, Rope and Twine
G. PULP, PAPER & PAPER PRODUCTS, PRINTING & PUBLISHING	
• Chemical & Stationery • Printing, Publishing & Packaging	• Pulp, Paper & Paper Products • Sanitary Towels & Diapers
H. MOTOR VEHICLE & MISCELLANEOUS ASSEMBLY	
• Boat/Ship Building • Automobile Components • Electric Generators Assemblers • Miscellaneous Machine & Equipment	• Bicycle • Motorcycle • Horology • Motor Vehicle Assemblers
I. DOMESTIC AND INDUSTRIAL PLASTIC & RUBBER	
• Rubber products	• Domestic and Industrial Plastics Foam
J. WOOD AND WOOD PRODUCTS (INCLUDING FURNITURE)	
• Wood Products and Furniture (Excluding Metal Furniture) Plywood & particle Board	

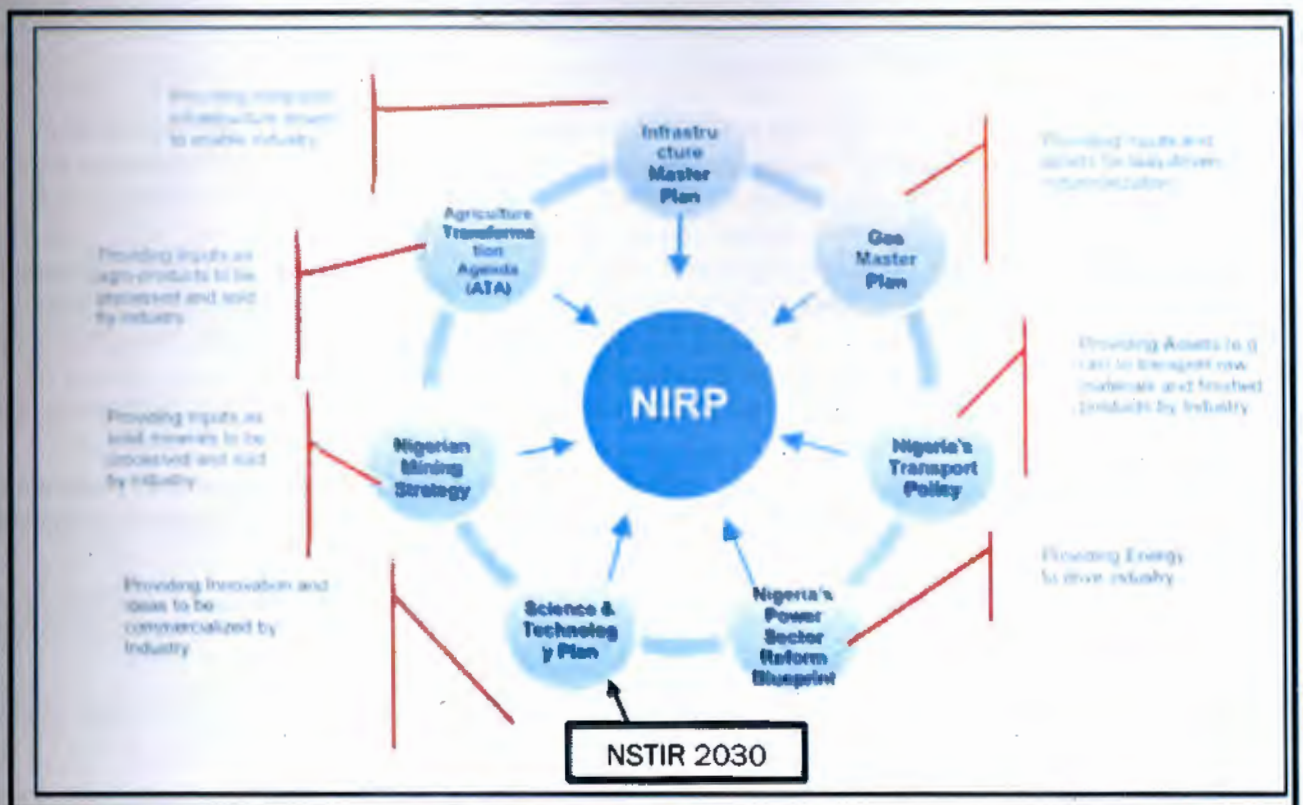


FIGURE 4A: THE INTERLINKAGES OF NIGERIA'S INDUSTRIAL REVOLUTION PLAN (NIRP) NOTING THAT NSTIR 2030 FILLS THE SLOT FOR SCIENCE AND TECHNOLOGY (24)

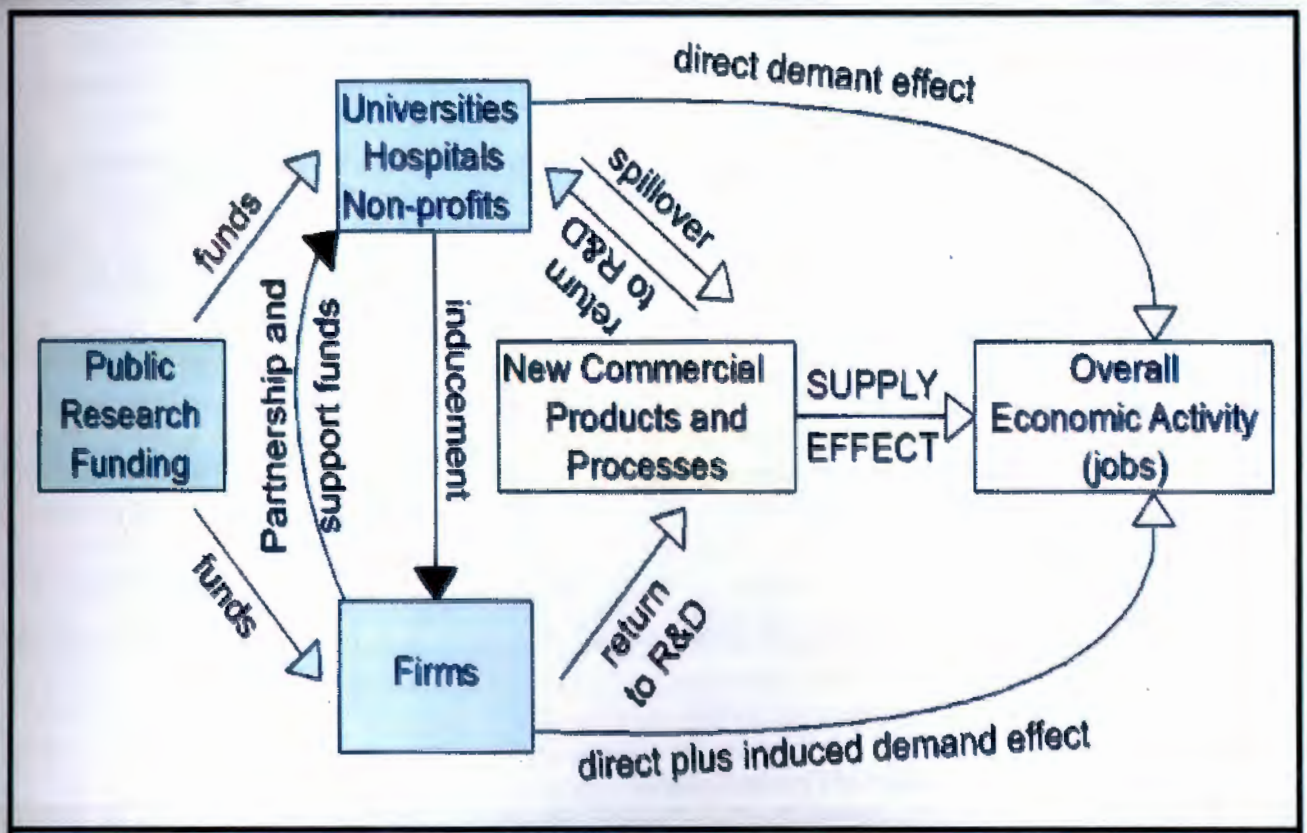


FIGURE 4B: CONFIGURATION OF INTERACTIONS AMONG PUBLIC, PRIVATE AND KNOWLEDGE CREATION ORGANIZATION THAT PROMOTE INNOVATION

2.0 FEATURES OF NSTIR 2030

2.1. The Objectives of NSTIR 2030

This Nigerian National Science, Technology and Innovation Roadmap NSTIR 2030 covers the period 2017-2030 which is longer than the periods of coverage of previous science and technology plans and policies, national development plans and sectoral plans. It derives from amalgamation of the objectives and mechanisms that were proposed in those categories of plans through detailed analyses, reconciliation of techniques, and framing of plans within strategic contexts. A compendium of the key plans is provided in Appendix 1 of this document. The objectives of this 2030 are those of Nigeria's National Policy on Science, Technology and Innovation (STI) of 2011, which has been re-affirmed in several meetings of stakeholders (11, 12), but recast with focus on strategic processes and implementation. The NSTIR 2030 objectives are presented below.

- To provide a long-term science and technology framework, support mechanisms for industrial revolution in Nigeria.
- To facilitate the creation and acquisition of knowledge for production, adaptation, replication, utilization and technologies to support Nigeria's technological and sustainable development aspirations.
- To support the establishment and strengthening of organizations, institutions, structures and processes for rationalization of decision-making and coordination and management of STI activities within an institutionalized national innovation system.
- To encourage and promote the creation of innovative enterprises that can beneficially utilize Nigeria's indigenous knowledge and technologies to produce marketable goods and services that compete with others in the global market.
- To coordinate and support the development of science and technology infrastructure to enable significant research for production of methodologies, models and data to support Nigeria's socio-economic development plans.
- To catalyze the conversion of deliverables from development to commercialized products that particularly maximize the use of Nigeria's home-grown technologies and raw materials.
- To facilitate and support the creation and up-to-date maintenance of reliable database on Nigeria's STI resources and activities.
- To improve and implement effective STI communication systems for enlightenment of the public about the critical role of STI in livelihood and inculcate STI culture in Nigerians.
- To devise and implement systems for identification and pruning of STI talent at all ages and educational levels in Nigeria through support and incentives to build a strong long-term workforce.
- To enable the implementation of sectoral plans and development plans at the State and community levels through injection of STI support.
- To coordinate the planning and catalyze the implementation of strategic projects such as those of space exploration, advanced computing, telemedicine, robotics advanced navigation systems, nanomaterials that can accelerate the emergence of Nigeria as a technologically developed country.
- To create and sustain reliable mechanism for adequate funding of STI activities in Nigeria.
- To create a platform for cultural reorientation of Nigerians to science and technology as a utility in life on a daily basis.

2.2. Key Features and Approach

2.2.1. Screening and Incorporation of Previous Plans

As time progresses, some elements of plans become irrelevant while others may still be relevant depending on the evolution of circumstances. For example, plans that may have been made several decades ago to install fixed line telephone systems throughout a region are now inappropriate and uneconomical due to advances in technology and life style changes that now favour mobile telephone systems. Also, the period of coverage of plans matter. If a plan is focused on short term needs, the

approach to addressing the identified challenges should be tactical. For projected, longer term needs, there is increase in uncertainty about visioned scenarios. So, the approach to planning extended systems should be strategic with allowances for some modifications as true configuration of factors unfold with time.

At least 220 documents have been reviewed to support the development of this NSTIR 2030. Among them are recommendations and policy statements developed by individuals, committees and commissions since Nigeria's independence in 1960. More recent national development plans have been reviewed in greater detail Plans that require the deployment of STI were identified and analyzed for framing and inclusion in this Roadmap. This is particularly true to recent plans and roadmaps developed by various Ministries of the Federal Republic of Nigeria. Many elements and plans of Nigeria's Vision 20:2020 which are schematically illustrated in Figures 5 and 6, are still current, not only because year 2020 has not come to pass but because a reasonably good job has been done in identifying sector-specific factors, needs and opportunities that still need to be addressed.

The Federal Ministry of Science and Technology (FMST) through its Establishment (National Science and Technology Act, CAP 276 of 1977), and the subsequent FMST Act No. 1 of 1980, has the mandate for coordination of STI policy and support activities in Nigeria. It has organized itself into the units shown in Table 4 to play its mandated role. The primary focus sectors of the units of FMST and roles that they will continue to play with greater intensity, on implementation of NSTIR 2030 programmes and project categories are presented in Table 4. Although STI is essential to all economic sectors, it is particularly required for any advance in industrialization of a country. For this reason, the components of Nigeria's Industrial Revolution Plan (NIRP, 2014) have been illustratively linked to programme categories of NSTIR 2030 as shown in Figure 7.

2.2.2. *Time-framing of Plans and Projects*

The strategic time-framing of NSTIR 2030 requires that it be segmented into shorter programme/project implementation periods to enable proper budgeting and tactical effectiveness toward attainment of strategic goals. As shown in Table 5, the implementation period has been broken into the following time segments.

- Short term (2017-2020), 4 years
- Medium term (2021-2025), 5 years
- Long term (2026-2030), 5 years

Actually, it is more conceptually convenient to view the duration labels as being pertinent to initiation of time frames from 2017 with short-term programmes terminating within 4 years; medium term ones terminating within 9 years; and long term ones terminating within 14 years, all expressed with respect to 2017 although they may not begin that early.

2.2.3. *Categorization of Projects and Programmes*

Categorization of projects plays a role in stressing the context and expediencies of the projects concerned. In universities where projects tend to primarily serve educational and general knowledge objectives, it is customary to configure analytical units into very basic/pure knowledge units (e.g. Dept. of Biology, Dept. of Materials Engineering, etc.). However, in a federal/mission-oriented research institute or center created to tackle a specific set of problems, the arrangement of research configurations which can be reshuffled from time to time as needed, needs to reflect the specific mission. This helps in reminding the programme personnel of each unit that deliverables are expected on the issues for which the unit was configured. Consequently, the specific categories of programmes required to accomplish the objectives of NSTIR 2030 have been formulated first, with the objective of letting personnel units to be configured to fit them as opposed to formulating programmes to serve the interests of existing units. Current personnel configurations may not be appropriate for strategic programmes. The categorization of NSTIR 2030 programmes and projects are presented below.

- Science policy and programmes support activities
- Science and technology infrastructure improvement
- Research and development intensification
- Training and talent deployment
- Technology deployment and commercialization

- Science Literacy improvement/stakeholders' engagement
- System monitoring evaluation and improvement

2.2.4. *Establishment of Linkages to Sectoral Roadmaps*

As earlier mentioned, many Ministries at the federal level, state agencies, the private sector and academic institutions have been developing STI roadmaps that cover various sectors of the Nigerian economy. Although FMST does not have operational control over those entities and their programmes and projects, it can provide national coordination as provided for in its mandate. Their coordination with incentives for synergy and collaboration among groups with similar STI interests will move the country speedily toward attainment of the goals of NSTIR 2030. In Appendix 1, the specific key initiatives covered by various national and sectoral plans/roadmaps are listed. The relevance of FMST's activities in each of the previously listed programmes areas, as well as specific research categories, are also indicated.

2.2.5. *Provision of Opportunities for Collaboration*

Collaboration on programmes and projects are usually possible when and where there are commonalities of interests and overlap of initiatives. While replication of initiatives may be minimal in FMST centers, institutes and units due to centrally operated approval processes, the same may not be true across various units and agencies of the Federal Government. Furthermore, there may be cases in which units of organizations that are outside the jurisdictional control are similes of those being implemented. In the former case, realignment of assignments may reduce wastage of resources. In the latter case, it may be opportunity to pull together resources and collaborate to achieve greater results.

The first step is the identification of opportunities for collaboration. NSTIR covers many activities such as publication of journal articles, newsletters, briefings and press releases; organization of conferences, seminar, and special broadcast; and general calls for collaborators. These programmes and activities can alert potential collaborators about existing and evolving opportunities such as those listed in this NSTIR 2030. In Appendix 2, regulatory Acts of the Nigeria legislature dating back to 1999 are posteriorly analyzed with respect to the technical requirements for their successful implementation. Many stakeholders of such regulations would have wanted to have the guidance herein supplied, to address their concerns about the configurations and provisions of some of the regulations during drafting stages or seek information on their implementation stages.

With respects to units of non-FMST Ministries and agencies, Appendix 3 is the list of the major entities that operate in the key industrial sectors that are covered with the programme areas of this Roadmap as indicated. The same is done for professional bodies and associations in Appendix 4 while several universities and associations are listed in Appendix 5 for contact and collaboration when and where possible.

2.2.6. *Special Targeting of Innovation and Its Diffusion*

Innovation is a non-traditional way of doing things with gains on the targeted objectives. Innovation can manifest as better approaches, processes, models, techniques, materials, systems, technologies or products. In the sustainable development targets of Nigeria, innovation will derive primarily from creation and use of knowledge to improve planned systems and/or existing systems. Intensification of research and development is the key. FMST operates several research centers and institutes in key technical areas of knowledge. Several transitions to entrepreneurship support activities have been made recently. Nevertheless, research and development activities of these units need to improve dramatically to the scale needed for realization of the objectives of NSTIR 2030. The research and development programme of this NSTIR 2030 has been treated in greater detail in Section 3.3 of this document. Specific projects and programmes are configured to promote R & D, the commercialization of its products and dissemination of information on innovation to stakeholders.

2.2.7. *Linkages to African and Global Initiatives and Plans*

Nigeria is a leading country in Africa and very important geopolitically at the global scale. The Nigerian diaspora embark on many deep professional activities and achieve international excellence in many fields of human endeavor. The country is also looked up to by many other countries to provide diplomatic and professional leadership. It has been a leader and contributor to peacekeeping operations in many counties. Thus, Nigeria must by necessity, be a key player in the formulation and implementation of STI-based Sustainable Development Goals (SDGs) of the United Nations which will cover the period

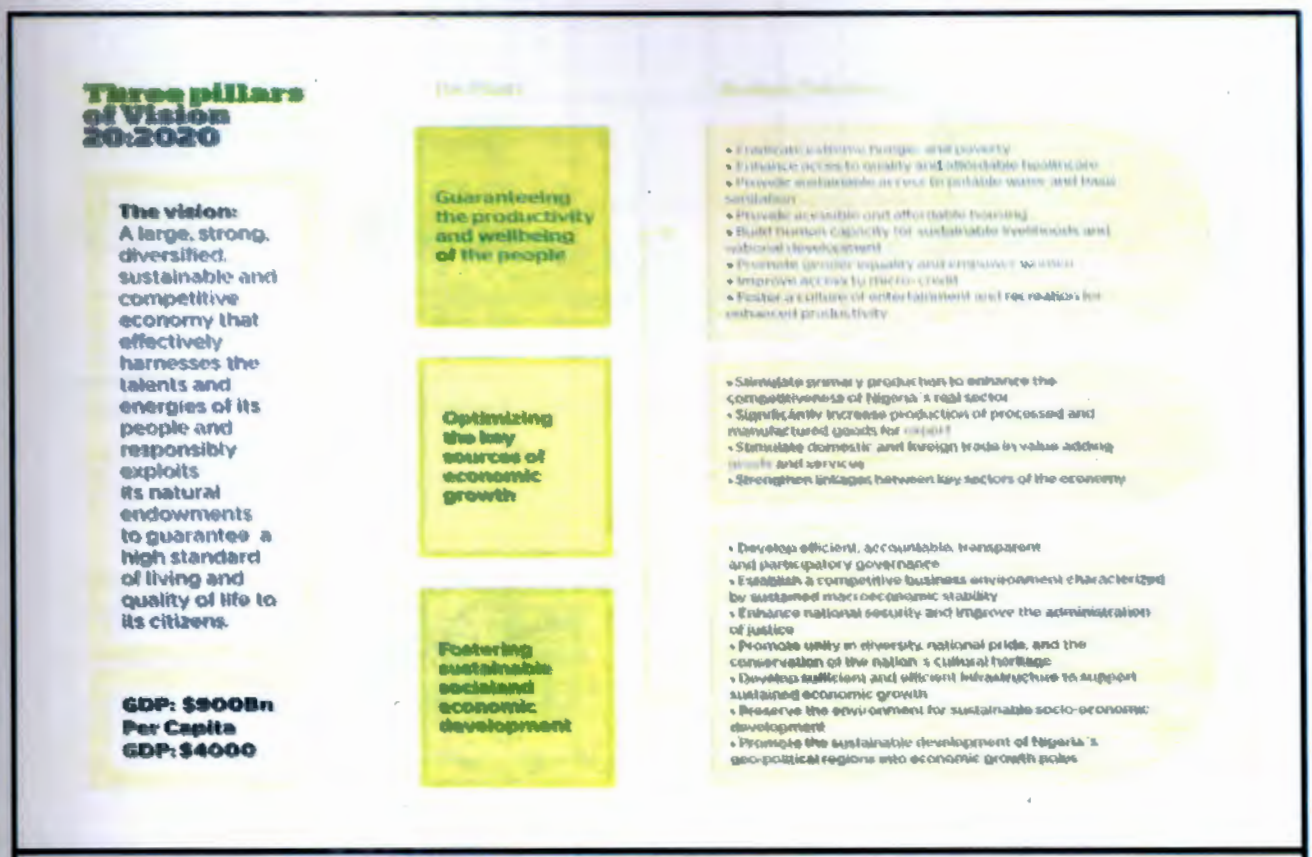


FIGURE 5: THE THREE PILLARS OF NIGERIA'S VISION 20:2020 DEVELOPMENT PLAN (198)

FIGURE 6: KEY MANAGEMENT PROCESSES FOR TRANSLATION OF VISION 20:2020 FROM INTENT TO RESULTS (198)

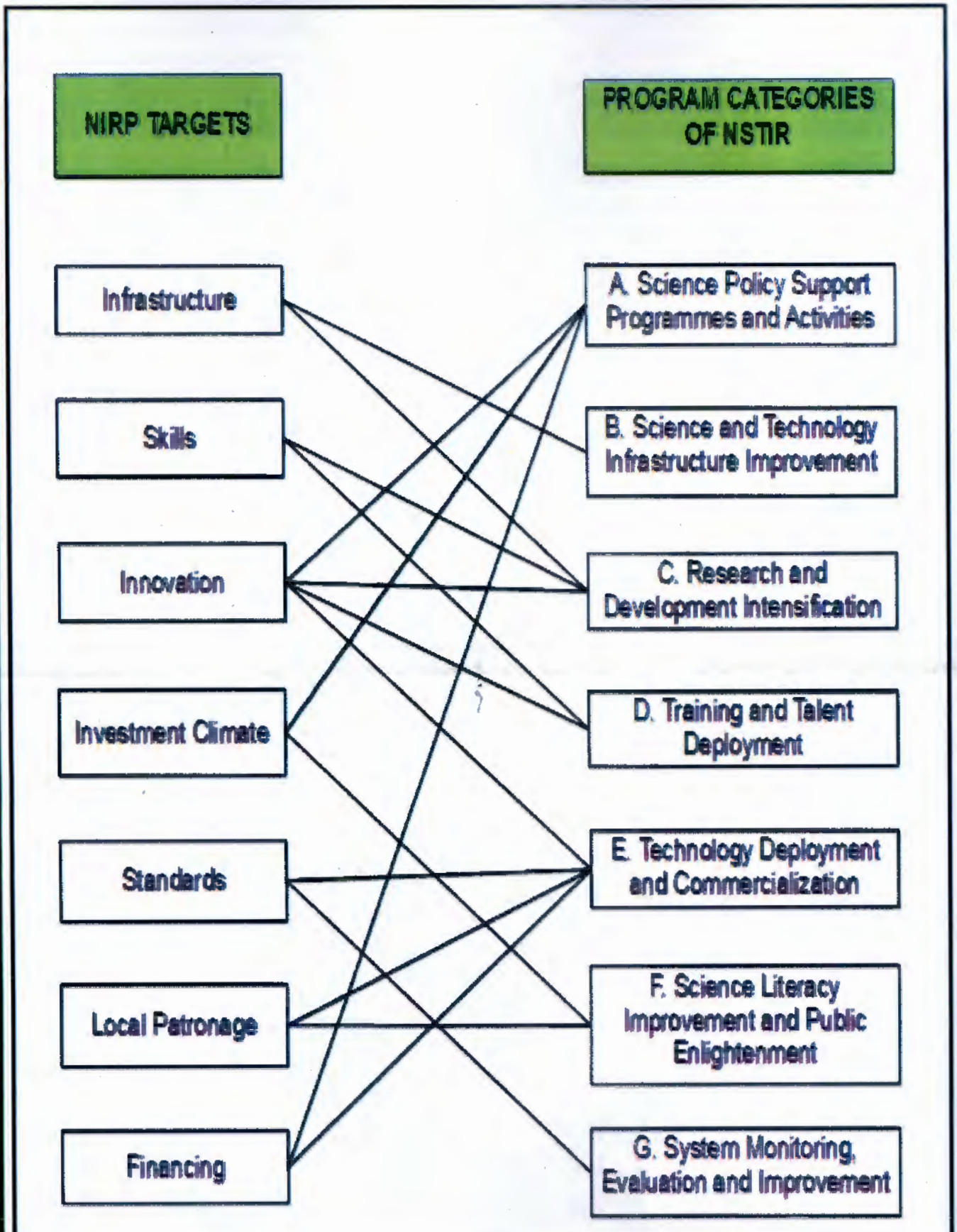


FIGURE 7: ELEMENTS OF THE NIGERIAN INDUSTRIAL REVOLUTION PLAN (NIRP) (JANUARY 2014) AND SUPPORT THAT THE NSTIR 2030 PROVIDES

TABLE 4: FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY UNITS AND AGENCIES AND THEIR APPROPRIATE ROLES IN THE IMPLEMENTATION OF THE NSTIR 2030

S/N	FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY (FMST) UNITS AND AGENCIES (non-administrative units)	KEY SOCIO-ECONOMIC SECTORS OF APPLICATION								NSTIR 2030 ROLES						
		AGRIC.	MANU.	MINING	ENERGY	OIL & GAS	CIVIL INF.	ICT	ENV., WATER & HEALTH	POLICY	INFRAC.	R&D	TRAINING & TALENT	TECH. & COMM.	SCIENCE LIT.	MONIT. EVAL. IMPROV.
1.	Renewable and Conventional Energy Technology Dept.		X		X	X				X			X	X	X	X
2.	Environmental Science and Technology Dept.								X	X			X	X	X	X
3.	Bioresources Technology Dept.	X	X		X				X	X			X	X	X	X
4.	Science and Technology Promotion Dept.	X	X	X	X	X	X	X	X	X	X		X	X	X	
5.	Health/Biomedical Sciences Dept.								X	X			X	X	X	X
6.	Finance and Accounts Dept.	X	X	X	X	X	X	X	X	X						X
7.	Human Resources Management Dept.	X	X	X	X	X	X	X	X	X			X			
8.	Procurement Dept.	X	X	X	X	X	X	X	X	X						X
9.	Special Duties Dept.	X	X	X	X	X	X	X	X	X						
10.	Reform Coordination Dept.	X	X	X	X	X	X	X	X	X						X
11.	Administrative Support Units: Legal Unit, Internal Audit, and the Press Unit	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12.	Chemical Technology Dept.	X	X	X	X	X			X	X						X
13.	Technology Acquisition and Assessment (TAA) Dept.	X	X	X	X	X	X	X	X	X	X		X	X		
14.	Information and Communication Technology (ICT) Dept.							X		X			X		X	
15.	Planning, Research and Policy Analysis (PRPA) Dept.	X	X	X	X	X	X	X		X			X		X	X
16.	Raw Materials Research and Policy Development Council (RMRDC)	X	X		X		X		X			X	X			

S/N	FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY (FMST) UNITS AND AGENCIES (non-administrative units)	KEY SOCIO-ECONOMIC SECTORS OF APPLICATION								NSTIR 2030 ROLES						
		AGRIC.	MANU.	MINING	ENERGY	OIL & GAS	CIVIL INF.	ICT	ENV., WATER & HEALTH	POLICY	INFRAC.	R&D	TRAINING & TALENT	TECH. & COMM.	SCIENCE LIT.	MONIT. EVAL. IMPROV.
17.	National Office for Technology Acquisition and Promotion (NOTAP)	X	X	X	X	X	X	X	X		X	X	X	X		X
18.	National Agency for Science and Engineering Infrastructure (NASENI)	X	X	X	X	X	X	X	X		X	X	X	X		
19.	Federal Institute for Industrial Research, Oshodi (FIRO)		X									X	X	X		
20.	Projects Development Institute (PRODA)	X	X	X	X	X	X	X	X		X	X	X	X		X
21.	National Board for Technology Incubation (NBTI)	X	X	X	X	X	X	X	X		X	X	X	X		X
22.	Nigerian Building and Road Research Institute (NBRRI)						X				X	X	X	X		
23.	National Research Institute for Chemical Technology (NARICT)		X	X	X	X	X		X		X	X	X	X		
24.	Energy Commission of Nigeria (ECN)			X	X	X				X	X	X	X	X	X	X
25.	Nigerian Institute of Leather Science and Technology (NILEST)		X									X	X	X	X	
26.	National Space Research and Development Agency (NSRDA)						X	X	X		X	X	X	X	X	
27.	National Biotechnology Development Agency (NABDA)	X			X				X		X	X	X	X	X	
28.	National Institute for Trypanosomiasis Research (NITR)								X			X	X	X	X	
29.	Sheda Science and Technology Complex (SHESTCO)	X	X	X	X	X	X	X	X		X	X	X	X	X	X
30.	Nigerian Natural Medicine Development Agency (NNMDA)	X	X						X			X	X	X		
31.	Nigerian Centre for Technology Management (NACETEM)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
32.	Nigerian Institute of Science Laboratory Technology (NISLT)	X	X	X	X	X	X	X	X		X		X	X	X	

TABLE 5: MAJOR SECTORS OF THE NATIONAL SCIENCE AND TECHNOLOGY IMPROVEMENT (NSTIR) 2030 ROADMAP RESPONSIBILITIES AND CONSTITUENT PROGRAMME SCHEDULES

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	A. SCIENCE POLICY SUPPORT PROGRAMMES AND ACTIVITIES																			
A.1	***MOBILIZATION OF THE NIGERIAN INTELLECTUAL RESOURCES FOR GROWTH AND DIVERSIFICATION OF THE ECONOMY***																			
A.1.1	*Creation of the National Science and Technology Advisory Groups in key economic sectors*	•					•	•												
A.1.2	*Institutionalization of a special science tax*	•						•	•											
A.1.3	*Commissioning of an Annual Nigerian National State Science and Technology Report*	•						•	•	•	•	•	•	•	•	•	•	•	•	•
A.1.4	*Establish policies and programmes for Popularization of science and technology in all MDAs*	•						•	•											
A.1.5	*Collaborate with appropriate Nigerian agencies to enhance implementation of local content programmes.*	•	•	•		•		•												
A.1.6	*Work with the Nigerian Congress to create and enforce made in Nigeria rules in all government contracts*	•						•												
A.2	***REWARD SYSTEM AND INCENTIVES IMPROVEMENT***																			
A.2.1	*Establish a new remuneration package for S&T professionals in government*	•	•			•			•											
A.2.2	*Implement National Science and Technology Support Awards in key sectors: Biosystems, manufacturing, science and tech. policy, agriculture, health, ICT and space systems, mathematical sciences, chemical systems and science communications*	•						•												
A.2.3	*Create three parallel remuneration tracks in federal science and technology*	•		•				•												

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE														
							SHORT TERM				MEDIUM TERM					LONG TERM					
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	establishments: administrative, technical; and entrepreneurship																			
A.3	*MANDATES REVIEW AND ENFORCEMENT*																			
A.3.1	*Enforce compliance with the Acts of Establishment of Nigeria's science and tech. agencies and institutions*	•					•													
A.3.2	*Work with the Federal Ministry of Education to enforce the 60/40 science/art admission ratio and increase it to 70/30 by 2030*	•		•				•												
A.3.3	*Double budget allocation to science and technology every 2 years up to 2030*	•							•		•		•		•		•		•	
A.3.4	*Work with the Federal Ministry of Finance and the Due Process Office to formulate a policy that requires the allocation of 5% of every budget of ₦200 million and above to science and technology support in federal contracts.*	•									•									
	B. SCIENCE AND TECHNOLOGY INFRASTRUCTURE IMPROVEMENT																			
B.1	*INCREASE IN SHARE OF THE MANUFACTURING SECTOR IN GDP FROM 4 TO 40% BY 2030*																			
B.1.1	*Create and implement technical/vocational infrastructure grant program*	•									•									
B.1.2	*Direct construction and PPP-formatted operation of electric power stations and water supply systems to industrial clusters and R and D stations in Nigeria*	•	•		•						•									
B.1.3	*Set up of materials testing/quality assurance laboratories in each of the 6 geopolitical zones of Nigeria*	•							•											
B.1.4	*Development of a GIS-capable National Data Repository in collaboration with statistics agencies*	•		•				•												

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B.2	*SPACE TRAVEL TO INSTALL 3 MORE NIGERIAN SATELLITES AND IMPROVEMENT OF CYBER-INFRASTRUCTURE TO SUPPORT S&T-BASED ENTREPRENEURSHIP*																			
B.2.1	*Establishment of a National Science and Technology Information Repository*	•							•											
B.2.2	*Space travel to launch at least, 2 more advanced Nigerian satellites and establishment of mission control and data center in Abuja*	•		•	•					•	•	•			•	•	•		•	•
B.3	*IMPROVEMENT OF FINANCING OF LARGE-SCALE INTEGRATED SCIENCE AND ENTREPRENEURSHIP*																			
B.3.1	*Creation of a Science and Technology Bank with productivity-focused rules and lending*				•					•										
B.3.2	*Provision of tax and other incentives to commercial banks to fund projects with high science and tech utilities*	•								•										
B.3.3	Lower interest rate on industrial/S&T facilities improvement loans by 200% without requirement of collateral (Govt. assumes risks)	•			•				•											
	C. RESEARCH AND DEVELOPMENT INTENSIFICATION																			
C.1	*RESEARCH RESOURCES UTILIZATION IMPROVEMENT*																			
C.1.1	*Categorization of all research and development entities in Nigeria with respect to the 10 focus areas and their alignment with federally sponsored research centers for collaboration*	•	•	•	•	•		•												
C.1.2	*Development of a directory of experts in Nigeria and their focus with storage in coded, editable format*	•						•	•											
C.1.3	*Creation of a National Science and Technology Library or library section to store both paper and electronic copies of articles and books.*	•								•	•	•	•							

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE														
							SHORT TERM				MEDIUM TERM					LONG TERM					
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C.1.4	*Work with appropriate Nigerian agencies at various jurisdictional levels to improve library resources in Nigeria*	•	•			•			•											
C.2	*IMPROVEMENT (TRIPLING) OF RESEARCH PRODUCTIVITY OF FEDERALLY-SPONSORED (FMST) LABORATORIES*																			
C.2.1	*Open up research staff employment opportunities to foreign experts on contract basis and advertise vacancies globally*	•	•	•							•									
C.2.2	*Establishment of centres of excellence or center suites of excellence to focus research on each of the Ten nationally target research areas.*	•										•	•	•	•	•	•			
C.2.3	*Increase the ratio of research and technical personnel to administrative personnel in federal research centers and laboratories to 8/2.*	•										•	•	•	•	•	•			
C.2.4	*Form external and qualified technical panels to evaluate the research productivity of FMST Centers both at the organizational and individual researcher levels*	•									•	•								
C.2.5	*Expansion and intensification of research in FMST centers and labs on each of the 10 thematic areas. (see Table 10).*	•																		
C.3	*IMPROVEMENT OF ALIGNMENT OF FEDERALLY SPONSORED CENTERS AND RESEARCH WITH NATIONAL SOCIO-ECONOMIC DEVELOPMENT TARGETS*																			
C.3.1	*Initiation of a research justification assessment programme for all federally funded centers to ensure alignment and contribution to national development targets*	•					•													
C.3.2	*Development and use of a uniform designation and cataloging system for reports form government funded projects*	•						•	•											

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C.4	PROVISION OF INCENTIVES TO PRIVATE SECTOR ORGANIZATIONS IN R&D INVESTMENT																			
C.4.1	Establishment of program support for large R&D joint ventures for companies that are in the same industry	•	•	•	•						•	•	•							
C.4.2	Opening up of Nigeria's current national research support programme to both public and private institutions	•							•											
C.4.3	Creation of a Nigerian National Research Foundation to support investigator-initiated research in nationally important thematic areas	•							•											
C.4.4	Annual National Research Gaps Synthesis (ANRGS) to support engagements by Nigerian researchers and institutions	•						•	•	•	•	•	•	•	•	•	•	•	•	•
C.4.5	Collaborate with the Federal Ministry of Education and Ministry of National Planning to provide grants for publication of STEM textbooks and technical guidance manuals in key development issues	•							•	•		•	•		•	•		•	•	
C.4.6	Creation of 5 National Research Chairs at the Distinguished, Senior and Junior levels in each of the 10 thematic areas (totally 50) for 10 year-periods every two years to be administered by the Nigeria's National Merit Agency (NNMA)	•							•		•		•		•		•		•	
	D. TRAINING AND TALENT DEPLOYMENT																			
D.1	TRAINING CURRICULA IMPROVEMENT																			
D.1.1	Incorporated entrepreneurship training in the curricula of Universities and Polytechnics	•							•	•										
D.1.2	Implementation of an FMST artisan training programme	•																		

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C.4	*PROVISION OF INCENTIVES TO PRIVATE SECTOR ORGANIZATIONS IN R&D INVESTMENT*																			
C.4.1	*Establishment of program support for large R&D joint ventures for companies that are in the same industry*	•	•	•	•						•	•	•							
C.4.2	*Opening up of Nigeria's current national research support programme to both public and private institutions*	•							•											
C.4.3	*Creation of a Nigerian National Research Foundation to support investigator-initiated research in nationally important thematic areas*	•							•											
C.4.4	*Annual National Research Gaps Synthesis (ANRGS) to support engagements by Nigerian researchers and institutions*	•						•	•	•	•	•	•	•	•	•	•	•	•	•
C.4.5	*Collaborate with the Federal Ministry of Education and Ministry of National Planning to provide grants for publication of STEM textbooks and technical guidance manuals in key development issues*	•							•	•		•	•		•	•		•	•	
C.4.6	*Creation of 5 National Research Chairs at the Distinguished, Senior and Junior levels in each of the 10 thematic areas (totally 50) for 10 year-periods every two years to be administered by the Nigeria's National Merit Agency (NNMA)*	•							•		•		•		•		•		•	
	D. TRAINING AND TALENT DEPLOYMENT																			
D.1	*TRAINING CURRICULA IMPROVEMENT*																			
D.1.1	*Incorporated entrepreneurship training in the curricula of Universities and Polytechnics*	•							•	•										
D.1.2	*Implementation of an FMST artisan training programme*	•																		

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
D.1.3	*Use about 30% of the National Youth Service Corp year to train and brief graduates on science and technology and associated opportunities*	•	•	•				•												
D.2	*CREATION OF DOMESTIC OPPORTUNITIES*																			
D.2.1	*Create and operate a Nigerian science and tech. diaspora engagement programme with allowance for up to 3-year sabbaticals and foreign-site-at-large roles*	•						•												
D.2.2	*Create a scientist-in-government and Scientist in enterprise support program*	•	•	•					•											
D.2.3	*Create science and Tech. internship programmes in federal centers and laboratories for students at the rate of 2000 per year*	•									•	•	•	•	•	•	•	•	•	
D.3	*EXPANSION OF ROLES AND OPPORTUNITIES IN THE FOREIGN ARENA FOR NIGERIAN SCIENCE AND TECH. PROFESSIONALS*																			
D.3.1	*Categorize and solicit African continental and global professional organizations to set up and operate their headquarters in Abuja in a specially constructed low-rent campus*	•						•	•	•	•	•	•	•	•	•	•	•	•	•
D.3.2	*Initiate collaboration with Nigerian tourism agencies to provide incentives for trade organizations to host international fairs and science and tech. summits/conferences in Nigeria*	•						•												
D.4	*GENERATE INTEREST AND AWARENESS OF THE SCIENTIFIC AND TECHNOLOGICAL HERITAGE OF AFRICANS IN GENERAL AND NIGERIANS IN PARTICULAR*																			
D.4.1	*Create scientific heritage programmes for TV broadcasts (documentaries and live discussions)*	•							•	•										
D.4.2	*Name streets and monuments after eminent scientists and analysts*	•	•							•										

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	E. TECHNOLOGY DEPLOYMENT AND COMMERCIALIZATION																			
E.1	*PROVISION OF TECHNICAL AND ENTERPRISE SUPPORT TO INCREASE NIGERIA'S TECHNOLOGY DEPLOYMENT LEVEL BY 400% IN 2030 RELATIVE TO 2017 FOR TECHNOLOGY DEPLOYMENT*																			
E.1.1	*Channel a minimum of 20% of SME funds to commercialization of R and D results*	•							•	•										
E.1.2	*Create the Department of Technology Policy and Planning in the National Planning Commission (NPC)*	•							•											
E.1.3	*Create technology incubation centers in all major Nigerian cities as a collaborative among government, corporations, Banks and Universities*	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•
E.2	*ATTAINMENT OF 30% SUBSTITUTION OF THE VALUE OF IMPORTED PRODUCTS IN NIGERIA BY 2030*																			
E.2.1	*Establish a legal frame work for progressive growth of local technologies and increase in raw material content of manufacturing industries in Nigeria*	•						•	•											
E.2.2	*Establish an electronic system for acquisition processing, storage and dissemination of information on new and advanced materials to researchers, entrepreneurs and policy makers.*	•																		
E.2.3	*Require that all federally sponsored institutions must establish research, development and commercialization units under a dedicated Deputy Vice Chancellor*	•							•											
E.2.4	*Require each federally funded institution to report on result of industrial and entrepreneurship activities annually*	•							•											
E.3	INCREASE THE NUMBER OF SCIENCE AND TECH BASED COMPANIES IN NIGERIA'S INDUSTRIAL CLUSTERS AND PARKS BY 300% BY 2030																			
E.3.1	*Provide incentives such as energy-share and low rent facilities to companies at government initiated industrial cluster parks*	•	•		•						•	•								

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE													
							SHORT TERM				MEDIUM TERM					LONG TERM				
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
E.3.2	*Site branches of appropriate government research laboratories at the industrial parks*	•								•	•	•								
	F. SCIENCE LITERACY IMPROVEMENT AND PUBLIC /STAKEHOLDERS ENGAGEMENT																			
F.1	***SCIENCE LITERACY IMPROVEMENT***																			
F.1.1	*Establishment of a science and technology museum*	•					•	•	•											
F.1.2	*Strengthening of existing science programmes through junior engineers and technicians clubs*	•		•				•												
F.1.3	*Strengthening of S and T talent hunting through Catch Them Young S&T Clubs throughout Nigeria*	•	•	•		•		•												
F.1.4	*Implementation of national science and technology competition*	•		•				•		•		•		•		•		•		•
F.2	***DIRECT SCIENCE ADVOCACY AND INFORMATION DISSEMINATION***																			
F.2.1	*Implement biweekly science and technology briefings on television and radio in English and local languages using Nigerian experts*	•					•	•	•	•	•	•	•	•	•	•	•	•	•	•
F.2.2	*Establish permanent sites for S&T Fairs at State and Local Government levels*	•	•							•										
F.2.3	*Serialize the biographies of eminent Nigerian scientists and engineers in newspapers and television using the NNOM Award Winner's lists and other non-political lists*	•						•	•	•		•	•	•			•	•	•	
F.2.4	*Implementation of an Annual Technology and Innovation Exposition Week in collaboration the private sector, academia, the state and the press*	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•

	SCIENCE AND TECHNOLOGY IMPROVEMENT SECTORS AND KEY PROGRAMMES	PRIMARY RESPONSIBLE ORGANIZATION					IMPLEMENTATION SCHEDULE														
							SHORT TERM				MEDIUM TERM					LONG TERM					
		FED. GOVT.	STATE GOVT.	ACAD.	CORPS	LGAS FOUND. & INT. ASSOC	17	18	19	20	21	22	23	24	25	26	27	28	29	30
F.2.5	*Initiate a programme of Science Diffusion at the Local Level (SDLL) in which weekly scientific briefings are given by local teachers and corpers in local languages at the village level*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
F.3	*COMMERCIAL SECTOR ENGAGEMENT PROGRAMME*																				
F.3.1	*Establish a programme by which Chambers of Commerce identify knowledge gaps and needs that confront them in efforts to increase productivity*	•			•			•	•	•	•	•	•	•	•	•	•	•	•	•	•
	G. SYSTEM MONITORING, EVALUATION AND IMPROVEMENT																				
G.1	*IMPROVEMENT OF STANDARDS AND QUALITY ASSURANCE AGAINST STANDARDS*																				
G.1.1	*Provide regulatory standards and develop quality assurance protocols for indigenous technologies especially in housing, food production and traditional medicine*	•							•	•	•	•	•								
G.1.2	*Develop metrics for evaluation of progress in Nigeria's science and technology system (innovation system)*	•					•	•													
G.1.3	*Develop a national ranking system for experts involved in science and tech. and other innovation programs in Nigeria*	•		•				•	•	•											
G.2	*ATTAINMENT OF 100% CHARACTERIZATION OF NIGERIA AS REGARDS DEVELOPMENT AND SCIENCE AND TECHNOLOGY INDICATORS*																				
G.2.1	Collaborate with Nigeria's statistics agencies on studies for data on all parameters of sustainable development goals (SDGs)	•						•	•	•	•	•	•	•	•	•	•	•	•	•	•
G.2.2	Create a depoliticized national development aspiration polling program for science and technology	•						•		•		•		•		•		•		•	

2016-2030 is coincident with this NSTIR 2030 which covers the period 2017-2030. Accomplishments derived from the implementation of the various programmes outlined in Table 5 will count for both Roadmaps.

Concerning socio-economic development of Africa, the venerable early pan-Africanist-Dr. Kwame Nkrumah stated in his first speech at the founding Summit of the Organization of African Unity (OAU, now AU) in Addis Ababa, Ethiopia on May 24, 1963 that ***"we shall accumulate machinery and establish steel works iron foundries and factories; we shall link the various states of our continent with communications ; we shall astound the world with our hydroelectric power; we shall drain marshes and swamps, clear infested areas, feed the undernourished, and rid our people of parasites and disease. It is within the possibility of science and technology to make even the Sahara bloom into a vast field with verdant vegetation for agricultural and industrial development".*** Indeed Africa has now developed its Agenda 2063: the Africa we want which targets continental sustainability, renaissance, and economic independence driven by science and technology as well as cultural awareness. The specific aspirations of Agenda 2063 (221) are state below.

1. A prosperous Africa based on inclusive growth and sustainable development
2. An integrated continent, politically united and based on the ideals of Pan-Africanism and the vision of Africa's Renaissance
3. An Africa of good governance, democracy, respect for human rights, justice and the rule of law
4. A peaceful and secure Africa
5. An Africa with a strong cultural identity, common heritage, shared values and ethics
6. An Africa whose development is people-driven, relying on the potential of African people, especially its women and youth; and caring for children
7. Africa as a strong, united and influential global player and partner

In planning attainment of the first aspiration, the plan advocates the emergence of "well-educated and skilled citizens, underpinned by science, technology and innovation for society in which knowledge **is the norm and no child misses school due to poverty or any form of discrimination" achievement of** Africa's **Agenda 2063** requires heavy investments in STI. With this realization, the African Union Commission worked with many partners to develop the Science, Technology and Innovation strategy for Africa 2024 (STISA-2024) (222) with the priority areas state in Table 6A. an inspection of those priority areas indicates that they reflect most of the focus areas are of NSTIR 2030. Thus, during implementation of the programmes of this Roadmap, extension to dovetail with STISA-2024 activities will be possible.

TABLE 6A: THE PRIORITY AREAS OF THE SCIENCE, TECHNOLOGY AND INNOVATION STRATEGY FOR AFRICA 2024 (STISA-2024) (222)

	PRIORITY AREAS	DETAILS
1.	Eradicate Hunger and ensure Food and Nutrition Security	• Agriculture/Agronomy in terms of cultivation technique, seeds, soil and climate • Industrial chain in terms of conservation and/or transformation and distribution infrastructure and techniques
2.	Prevent and Control Diseases and ensure Well-being	• Better understanding of endemic diseases - HIV/AIDS, Malaria Hemoglobinopathies • Maternal and Child Health • Traditional Medicine
3.	Communication (Physical & Intellectual Mobility)	• Physical communication in terms of land, air, river and maritime routes equipment and infrastructure and energy • Promoting local materials • Intellectual communications in terms of ICT
4.	Protect our Space	• Environmental Protection including climate change studies • Biodiversity and Atmospheric Physics • Space technologies, maritime and sub-maritime exploration • Knowledge of the water cycle and river systems as well as river basin management
5.	Live Together – Build the Society	• Citizenship, History and Shared values • Pan Africanism and Regional integration • Governance and Democracy, City Management, Mobility • Urban Hydrology and Hydraulics • Urban waste management
6.	Create Wealth	• Education and Human Resource Development • Exploitation and management of mineral resources, forests, aquatics, marines etc. • Management of water resources

2.2.8. *Tracking of Competition by Other Countries*

Competition in the global markets is a factor in the distribution of wealth, stealth, and health among nations. Nations that are highly productive produce goods that beat out others in competition with the resulting generation of revenues and jobs to improve socioeconomic conditions domestically. The stakes are high for the deployment of STI to support socio-economic development systems of countries. Many countries have systems in place for improvement of their STI performance. The graph of global innovation ranking index versus GDP per person (at purchasing power parity) presented in Figure 8 as constructed from data (163) shows a positive correlation which indicates that-the greater the innovation index, the greater the GDP per person. As evident in Figure 8, most of the technologically advanced countries that rank high on STI have high GDP per capita. This is the status that Nigeria seeks through implementation of NSTIR 2030.

Figure 9 shows the Gross Domestic Expenditure on Research and Development (GERD) financed by governments of many countries as a share of their respective GDPs for the period 2005-2013. Of the several countries studied, Nigeria (at 0.22%) ranked the lowest along with Mexico and Turkey before 2008. Thereafter, Mexico steadily increased its S&T investment while Turkey increased it minimally. Nigeria's investment has remained constant at the low level. Table 6B and Figure 10 also show the socio-economic indices of many competing countries for cross matching with Global Innovation Rankings. Socio-economic advantages correlate with innovation. One of the objectives of this Roadmap is to diversify the sources of S&T support to increase available resources for input into Nigeria's STI programmes so that the country can favourably compete with others within and outside.

Germany has the EU's largest innovation system. As shown in Figure 11, the German Innovation Policy consists of 5 core elements: enhancement of competitiveness to increase prosperity; arouse curiosity to promote forward-thinking, provide the basis for creativity and innovation, increase innovative strength and enhance value creation, and strengthen cooperation to support implementation. From a GERD funding level of 1.92% of GDP in 2011, Germany targeted the level of 3.0% by 2015. All of those approaches are also covered in one form or the other in NSTIR 2030.

Singapore is another high-technology country that makes huge investments in STI. For its small population, this is quite remarkable. Singapore's Science and Engineering Research Council (SERC) supports four key manufacturing sectors: electronics, ICM, chemicals, and engineering. These units and their interactions are illustrated in Figure 12 (197). Through its GET-Up Scheme, Singapore provides help to local entreprises to improve their global competitiveness. To illustrate the country's strategic approach to STI implementation, a process of technology scans was performed by the domestic research community, it provided foresights on major social, economic, technological and political trends to the year 2020 to enable better framing of the country's STI and development plans.

Figure 13 shows the elements of Japan's Vision 2050 programme. The plan is framed with improvement of the quality of life as the basis. Everything else is tied to it. Treatment and appreciation of international issues are covered. This is rational in the sense that foreign markets have to be understood, and Japan is a part of the global community. Also, Japan has a very long term plan-Vision 2050 (15). It has broken it into manageable time segments to reduce uncertainty. The policy documents are followed up with a detailed document that focuses primarily on research and development (69). It is entitled *"Contributing to Society through Science, Technology and Innovation"* with a presentation of the *"Hamaguchi Plan"* in which the following specific objectives are described along with plans to attain them: deepening of its close and global partnerships with universities, public research institutes and industrial partners; refinement of programmes and business structures for a more effective and efficient implementation; and contribution to improvement in the quality of life of the people of Japan as well as the sustainable development of society.

The STI issues of focus by Finland are internationalization of its educational system, research and innovation; broadening of the scope of R&D and creation of new growth enterprises in all sectors with focus on SMEs; and addressing of green growth through radical system changes. One notable objective of this plan is internationalization. Nigerian universities and research institutes lack foreign analysts. Nigeria can learn from this approach which the United States, Canada and European countries have used to perfection. Internationalization brings new talent to host countries. The countries gain from domestic grafting if new ideas are assessed with local ones. Table 7 shows Finland's SWOT analyses with rationale that have made it an industrial power globally despite its small size, harsh climate and small population. In 2010, Finland's GERD was 3.88% of GDP. There was a plan to increase it to 4% by 2015. Finland has

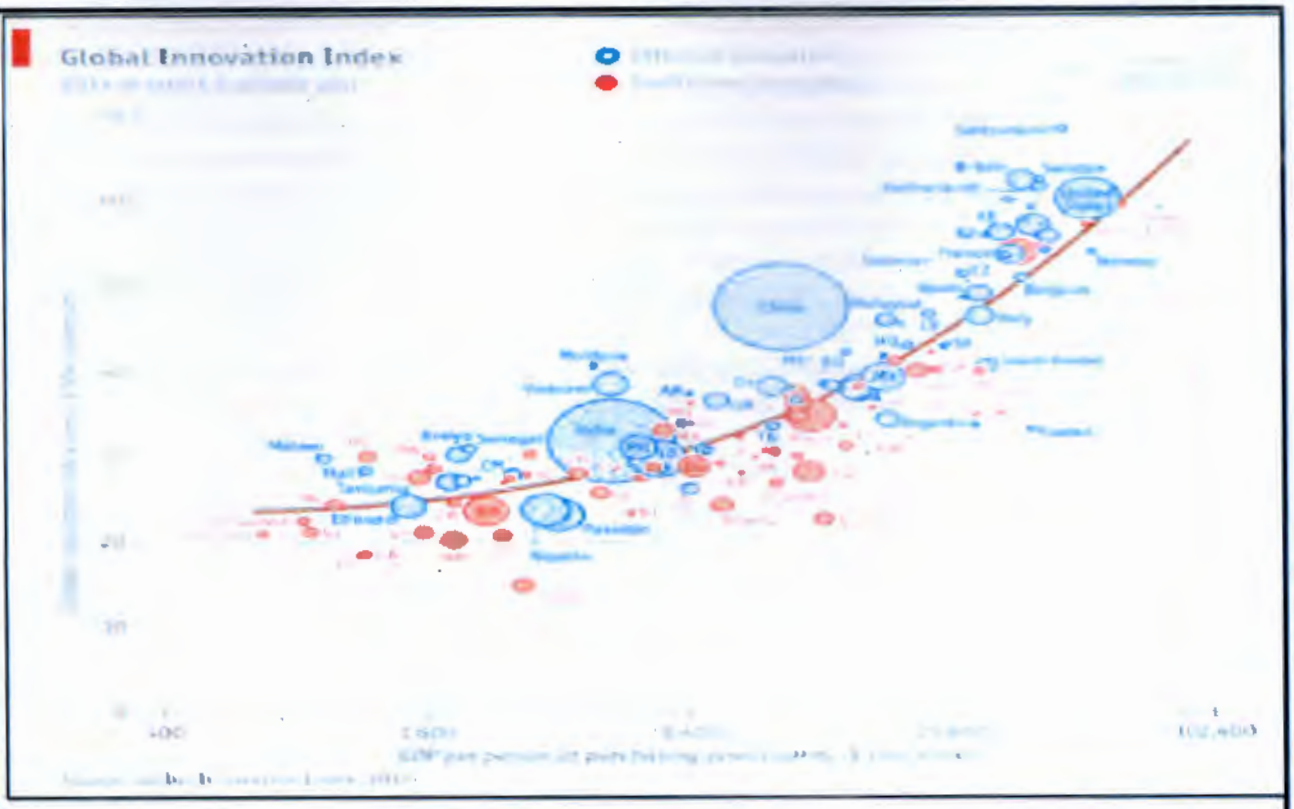
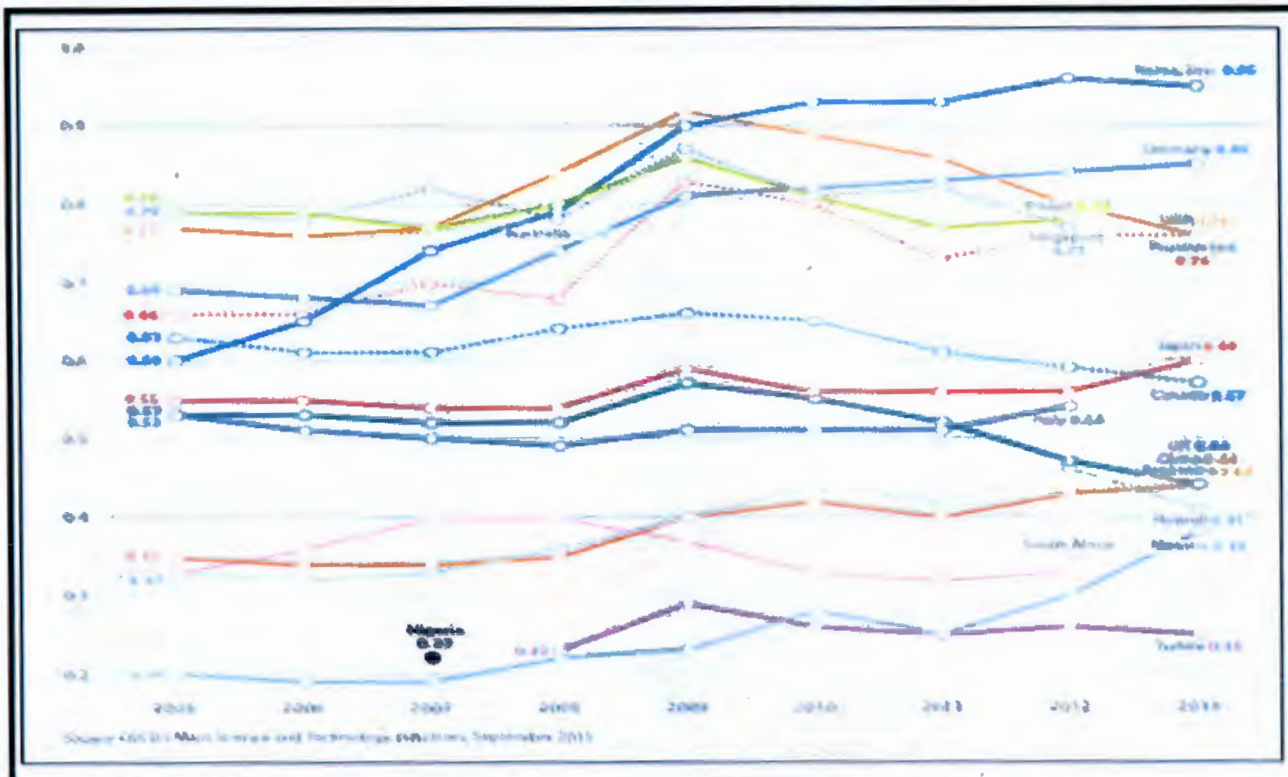


FIGURE 8: GLOBAL INNOVATION INDEX, 2014 OR LATEST AVAILABLE



Source; Adapted from OECD's Main Science and Technology Indicators, September 2015

FIGURE 9: GROSS DOMESTIC EXPENDITURE ON RESEARCH AND DEVELOPMENT GERD FINANCED BY GOVERNMENT AS A SHARE OF GDP, 2005-2013 (%)

TABLE 6B: RATIONALE FOR SELECTION OF COUNTRIES FOR SCIENCE AND TECHNOLOGY REVIEWS WITH RESPECT TO ASSESSMENT OF FACTORS FOR CONSIDERATION IN NIGERIA'S SCIENCE AND TECHNOLOGY ROADMAP.

Selected Countries		2015 Global Innovation Rankings	2014 Global Human Development Rankings	FACTORS OF INTEREST IN NIGERIA'S SCIENCE & TECHNOLOGY PLANNING AND DEVELOPMENT							
				Similar Economic Development Stage	Economic Success in Diversity	2015 GDP per Capita (US$)	High National Industrial Productivity	High Social Satisfaction	High Technological Advancement	Adult Literacy Rate (%)*	National Development Timeframe (Planning)
1.	Nigeria	128	152			2,640				59.57	2030
2.	Brazil	70	75	X	X	8,539	X	X	–	92.59	
3.	Canada	16	9	–	–	43,249	X	X	X	99.00	
4.	China	29	90	–	–	8,028	X	X	X	96.36	
5.	Egypt	100	108	X	–	3,615	–	–	–	75.84	
6.	Finland	6	24	–	–	42,311	X	X	X	100.00	
7.	Germany	12	6	–	–	41,313	X	X	X	99.00	
8.	India	81	130	–	X	1,598	X	X	X	72.23	
9.	Japan	19	20	–	–	32,477	X	X	X	99.00	
10.	Mauritius	49	63	X	X	9,252	X	X	–	90.62	
11.	Mexico	57	74	X	–	9,005	–	X	–	94.55	
12.	New Zealand	15	9	–	–	37,808	X	X	X	99.00	
13.	Rwanda	94	163	X	–	697	–	X	X	71.24	
14.	Singapore	7	11	–	–	52,889	X	X	X	96.77	
15.	South Africa	60	116	X	X	5,724	X	–	X	94.60	
16.	South Korea	14	17	–	–	27,222	X	X	X	97.90	
17.	United Kingdom	2	14	–	X	43,876	X	X	X	99.00	
18.	United States	5	8	–	X	56,116	X	X	X	99.00	

* Latest available value provided by UNESCO or estimated

Source: World Bank (online databank); UNDP; and Cornell University, INSEAD, and WIPO (2015)

Source: Chart constructed from UNDP (online databank); Cornell University, INSEAD, and WIPO (2015)

FIGURE 10. CORRELATION BETWEEN GLOBAL INNOVATION AND HUMAN DEVELOPMENT RANKINGS.

FIGURE 11 . THE FIVE CORE ELEMENTS OF THE GERMAN INNOVATION POLICY (193)

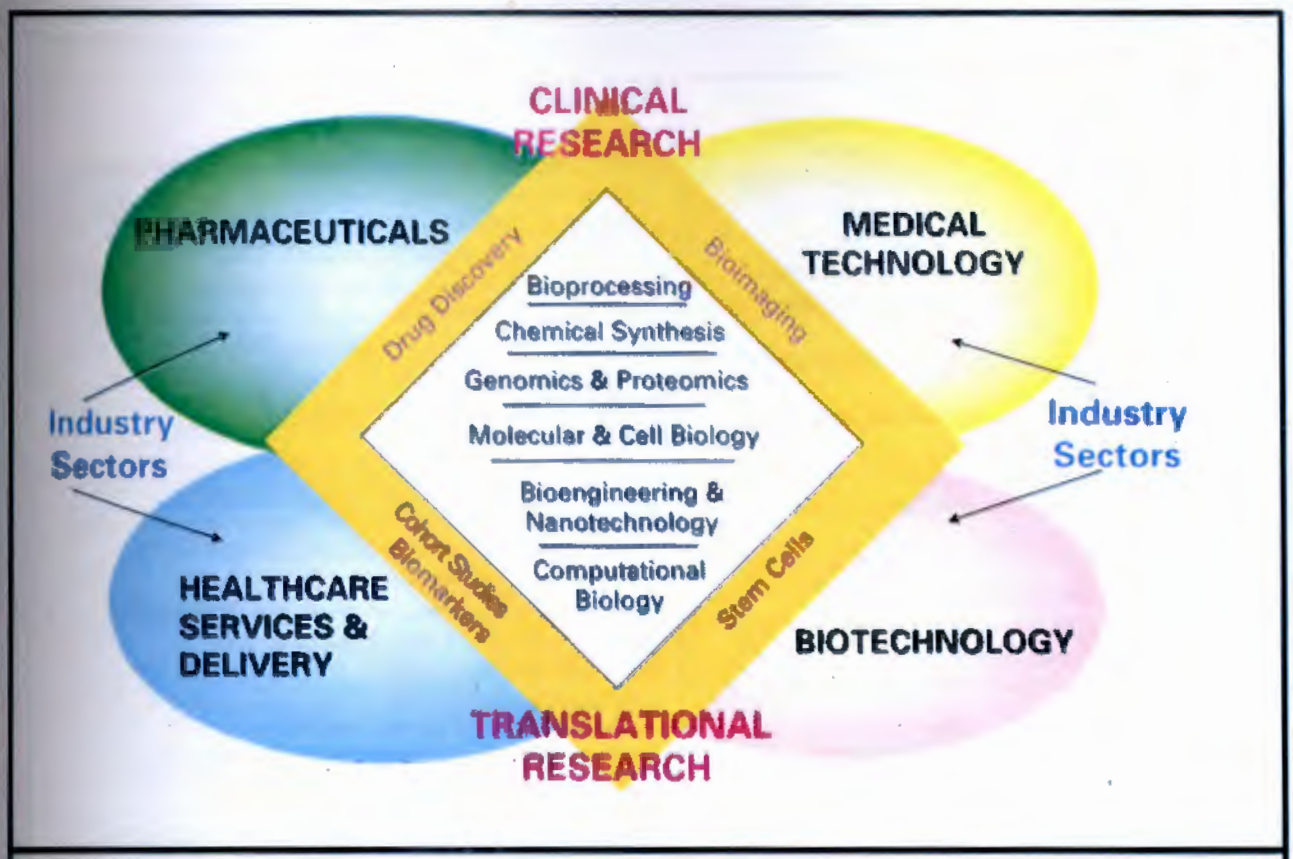


FIGURE 12. SINGAPORE'S STI CLUSTERS (197)

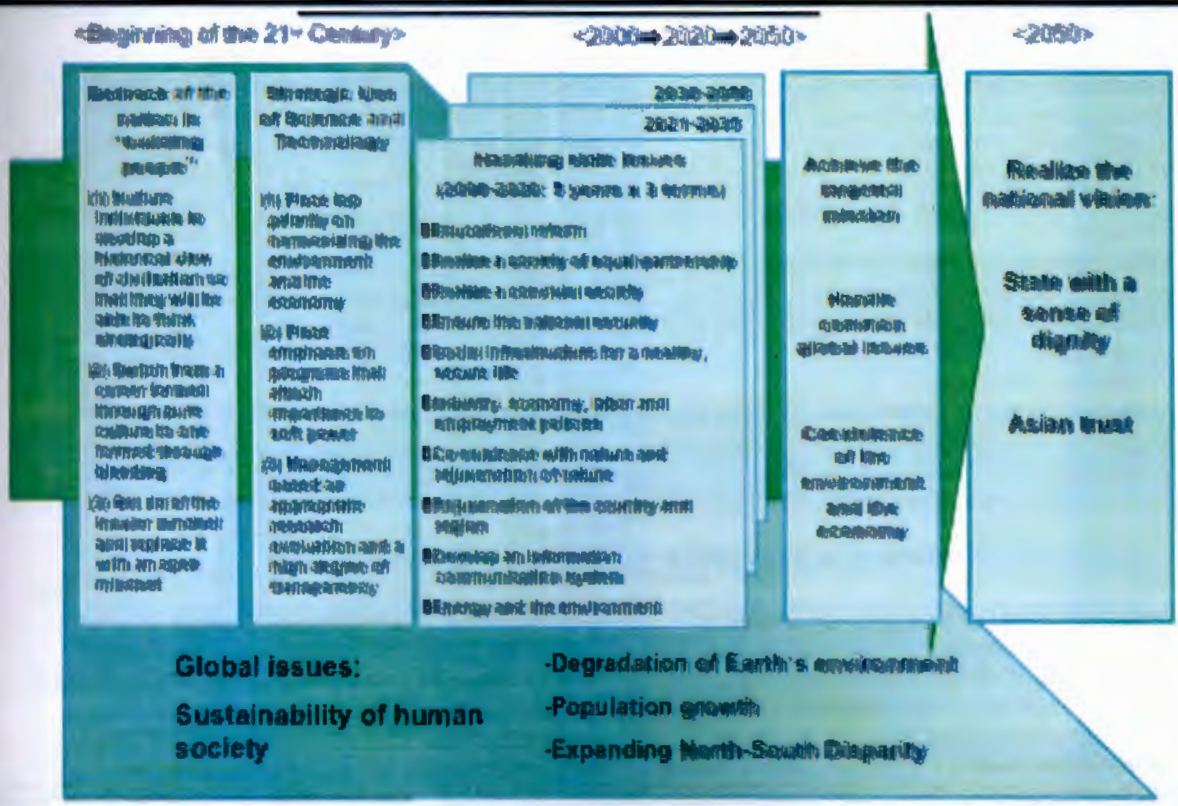


FIGURE 13: JAPAN VISION 2050-PRINCIPLES OF STRATEGIC SCIENCE AND TECHNOLOGY POLICY TOWARDS (15)

TABLE 7: THE CHALLENGES, DRIVERS AND OPPORTUNITIES OF THE FINNISH STI POLICY (195)

Strengths	Opportunities and means
- Finland having become an active partner in international co-operation quite recently but rapidly; a very high rate of participation in the activities of international organisations - Science and technology policy implemented on a long-term basis; investment in R&D regarded as important - Well-functioning education, research, and innovation systems - Openness, intensive co-operation, and competitiveness of the innovation system - A high proportion of competitive R&D funding - A high level of education among the population - Brain drain relatively small - A high proportion of women among researchers and PhDs by international standards - A large number of researchers, who make up a large percentage of the employed - Research volume, quality, and impact at a good international level - Active international patenting - Finland's good reputation: reliable, safe - Knowledge-intensive businesses remaining in Finland - Good co-operation between business enterprises and public research - Finnish enterprises being internationally networked	- Effective and efficient national innovation environment boosting competitiveness ++ internationalisation of the activities and organisations of the innovation system - An enhanced knowledge base and R&D environment, attracting new foreign investments and intellectual resources to the country and improving Finland's position as an attractive region for business operations - Looking for competence where it is best: global and diverse international co-operation, going beyond the EU - Compensating for the small size and geographical remoteness with active, strategically sound co-operation - Prioritised pooling of limited, fragmented resources - Open-minded and sufficient support for creativity and innovation - Enhancing foresight activities and their linkage with decision-making and strategic steering - Implementation and productisation of social innovations - Enhancing positions in international co-operative institutions and R&D organisations - Improving the organisational and functional structure of the innovation system and the division of tasks - Developing business and marketing competence - Creating a favourable business environment and promoting entrepreneurship - Supporting the creation and growth of businesses that focus on R&D and exploitation of leading-edge expertise
Weaknesses and framework conditions	**Threats**
- Strong dependence on global trends - Remote location from global market centres, geographically distant from the centres of Europe - Difficulties in relation to attractiveness and growth: a small domestic market area, a limited number of inhabitants, a small language area, and severe climate - A relatively low level of internationalisation by European standards - Limited economic and intellectual resources: a low volume of knowledge and competence in many fields and the cutting edge of scientific research in the hands of a select few - Problems with venture capital (amount, availability, matching of demand and supply) - Deficiencies in marketing and business competence and in knowledge and innovation management - A small number of spin-off businesses from universities and research institutions - Fragmented research activities: resources allocated to a large number of small units - A small number of highly educated foreign experts, students, and researchers - A small number of growth-oriented enterprises - Enterprises and parts of their operations moving abroad - Low inflow of foreign direct investments; negative balance of investment	- There is an international economic recession and decline in Europe - Finland does not attract foreign direct investments, R&D investments, researchers, and students - Finland is less active in the EU and global R&D co-operation - The operational foundations of the EU become weaker: more internal conflicts and less commitment and co-operation - National interests are overemphasised in international co-operation - Focus is missing: participation in too many projects with scarce resources - Links among research and economic development, employment, well-being, and innovations grow weaker - Diminishing age groups and an ageing population undermine the balance of the public economy, the room for economic manoeuvring, and the supply of highly skilled labour - The regulatory framework does not support the transfer of research results from R&D organisations to businesses and the commercialisation of results - Availability of competence in the labour market is insufficient: education does not meet labour market needs - The number of new R&D-intensive businesses declines - The favourable development of public R&D funding stagnates - Business R&D expenditure starts to decline - Businesses increasingly move their operations abroad - Brain drain increases: high competence moves abroad

TABLE 8: CANADA'S LEGACY OF INNOVATION (194)

A Legacy of Innovation

Throughout our history as a nation, Canadians have been pioneers in scientific and technological achievement. We have turned research and ideas into products, jobs and a healthier, safer world. Here are some of Canada's successes:

1860s - steam automobile

1870s - telephone / standard time

1880s - rotary railroad snowplow

1890s - basketball

1900s - Robertson screw / Marquis wheat / AM radio

1910s - echo sounding / hydrofoil speed record

1920s - insulin treatment for diabetes / snowblower / electric variable pitch aircraft propeller

1930s - snowmobile / first electron microscope in North America / portable two-way radio

1940s - voltage-controlled electronic music synthesizer / first g-suit flown in combat / co-discovery of carbon-14

1950s - co-invention of alkaline dry battery / external heart pacemaker / cobalt bomb radiation therapy

1960s - Alouette scientific satellite / co-invention of charge-coupled device

1970s - IMAX motion picture system / Anik domestic communication satellites

1980s - Canadarm / automated synthesis of DNA sequences

1990s - BlackBerry

2000s - D-Wave One: world's first commercially available Quantum computer

2010s - ATLAS subatomic particle sensor (Higgs Boson) / monoclonal antibodies for Ebola treatment / detection of microbes in deep Precambrian rocks / high-pressure direct injection natural gas diesel engine.

[1] Science, Technology and Innovation Council. Aspiring to Global Leadership: 2012 report on the state of Canada's science, technology and innovation system. Media Release (Ottawa May 21st, 2013).

developed and published a detailed Roadmap for Research Infrastructure 2014-2020 (189). Nigeria's GERD is approximately 0.22% of GDP.

As shown in Table 8, Canada has a long legacy of STI. Many groundbreaking achievements have resulted from deep investment in STI and R&D. The country has a very elaborate R&D system with very many incentives for high-performers. In its current plan as presented in Table 9 (194), it is focusing on agriculture, health and life sciences, natural resources and energy, information and communication technologies, and advanced manufacturing. Interestingly, these focus areas are reasonably close matches to the focus areas and issues of the NSTIR 2030 research programme. Thus, there could be opportunities for collaboration with Canadian public research organizations and centres.

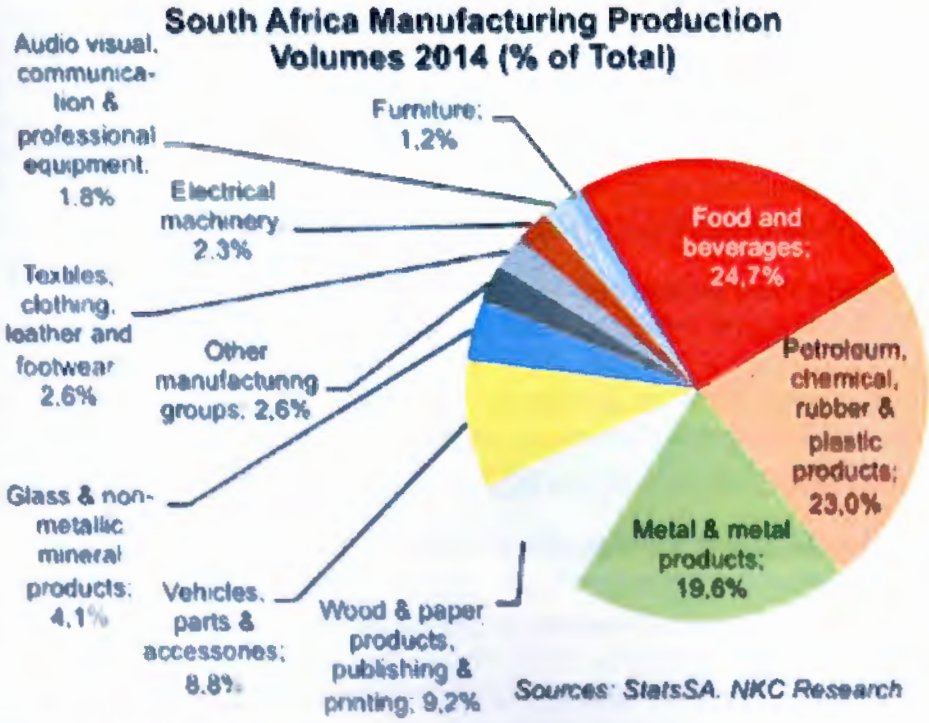
New Zealand also has an elaborate research agency that supports its national sustainable development aspirations. As shown in Figure 14, it focuses on very high technology areas that will drive the country rapidly to leadership in high-tech industrial development and national stealth. Some of the areas are covered by NSTIR 2030.

Within the continent of Africa, South Africa and Egypt are roughly in the same geopolitical category as Nigeria and compete in many realms of human endeavour. Figures 15 and 16. show some elements of the two countries' economic status, respectively. Manufacturing activity is deeper in South Africa than in Nigeria. Also, its universities are more international and better equipped to advance STI than Nigerian institutions. Egypt is also in manufacturing. It used to host a large number of branches of foreign companies to its advantage. Its universities are also ranked highly in Africa. Nigeria has to make significant improvement in STI to restore the country to its rightful place as the socio-economic heartbeat of Africa and strong competitor/collaborator with many other countries worldwide.

TABLE 9: CANADA'S RESEARCH PRIORITIES AND FOCUS AREAS (194)

Research Priorities	Focus Areas
Environment and Agriculture	• Water Health, Energy, Security • Biotechnology • Aquaculture • Sustainable methods of accessing energy and mineral resources from unconventional sources • Food and food systems • Climate change research and technology • Disaster mitigation
Health and Life Sciences	• Neuroscience and mental health • Regenerative medicine • Health in an aging population • Biomedical engineering and medical technologies
Natural Resources and Energy	• Arctic: Responsible development and monitoring • Bioenergy, fuel cells and nuclear energy • Bio products • Pipeline safety
Information and Communications Technologies	• New media, animation and games • Communications networks and services • Cybersecurity • Advanced data management and analysis • Machine-to-machine systems • Quantum computing
Advanced Manufacturing	• Automation (including robotics) • Lightweight materials and technologies • Additive manufacturing • Quantum materials • Nanotechnology • Aerospace • Automotive

FIGURE 14: ALIGNMENTS OF NEW ZEALAND'S RESEARCH AND DEVELOPMENT PROGRAMMES (190)



Source: KPMG (2015), Manufacturing in Africa

FIGURE 15: SOUTH AFRICA'S MANUFACTURING PRODUCTION VOLUMES 2014 (% OF TOTAL) (201)

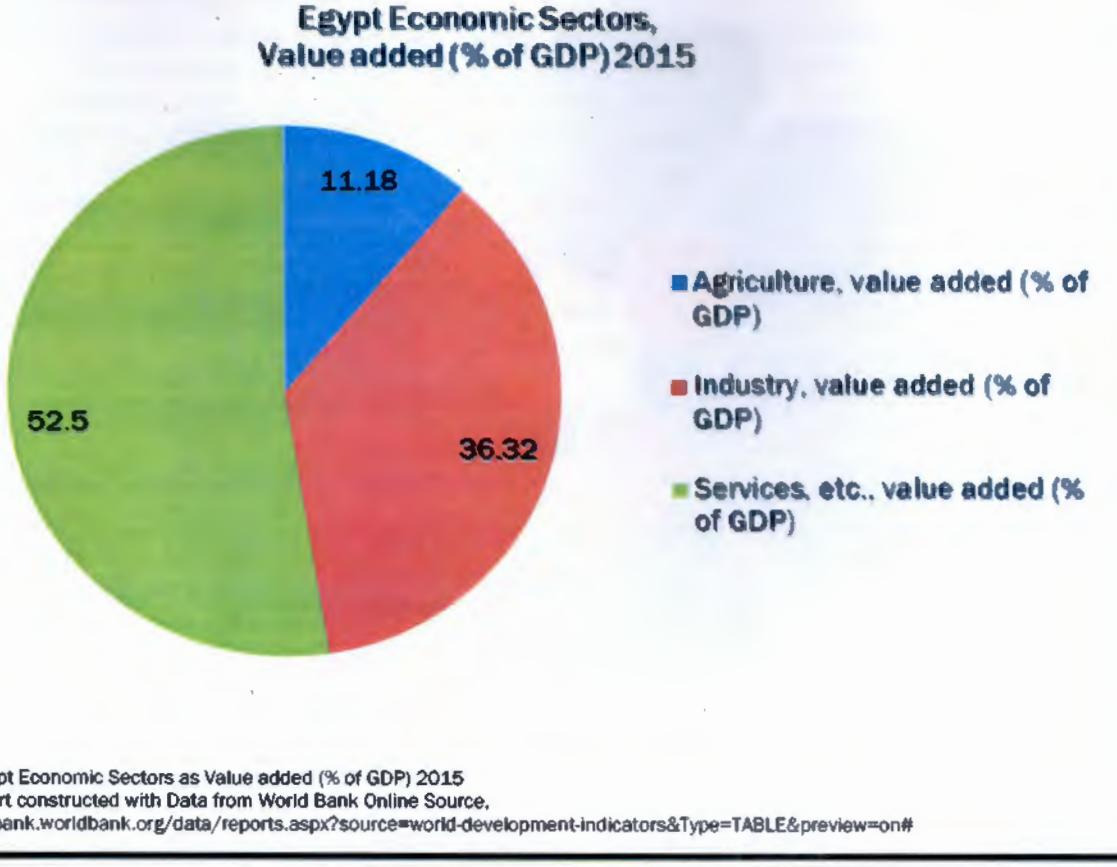


Chart . Egypt Economic Sectors as Value added (% of GDP) 2015
Source: Chart constructed with Data from World Bank Online Source,
http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators&Type=TABLE&preview=on#

FIGURE 16: CONTRIBUTION OF VARIOUS SECTORS TO EGYPT'S 2015 GDP (201)

3.0 PROGRAMMES, PROJECTS AND SCHEDULES OF NSTIR 2030

The programme categories described in section 2.2.3, were presented in greater detail in Table 5. Therein, specific projects are listed with their schedules within broad project categories. In this chapter, the utility of the programmes and projects listed in Table 5 are further discussed. Detailed project lists and prospective collaborators are provided in section 3.3 which deals with research. Figure 17 shows the relationship between NSTIR 2030 and some of the previously developed initiatives.

3.1. Science Policy Support Programmes and Activities

For the NSTIR 2030 period, project sub-categories that will be covered in this major category are as follows:

- Mobilization of the Nigerian intellectual resources for growth and diversification of the economy
- Improvement of reward systems and incentives for STI personnel to enhance performance
- Review of the mandates of science agencies in Nigeria to identify duplications, gaps and opportunities

Specific projects within these sub-categories are presented in Table 5. Also, in order to transform from a developing to a developed country by 2030, Nigeria has to develop and implement more rational methods for decision making on critical aspects that define its socio-economic well-being. As illustrated in Figure 18, Nigeria's resources need to be deployed for development through an analytical framework that includes predictions/forecasts and decision support tools. If such systems were significantly employed in the past, better success levels would have been achieved with the serial national development plans that have been implemented since independence in 1960. In this regard, rational decision making methods require information gathering and management and non-relegation of knowledge to the background on critical matters of national survival and economic progress, Figure 19

is the information sourcing, storage and management architecture that the Federal Government of Nigeria, beyond the mandate of FMST, needs to adopt to support its policies and decision-making across all sectors of the economy.

3.2. Science and Technology Infrastructure Improvement

The sub-categories of projects here are designed to provide infrastructure for the operation of Nigeria's STI system. Effective implementation of the system would enable the industrialization and the dependent economic diversification that Nigeria will continue to target during the foreseeable future. The Industrial Cluster approach that is being initiated to quicken industrialization of Nigeria requires the roles that have been advocated (198) for various stakeholders as summarized in Table 11. As evident in Table 12, much has been done to identify the viable products which various geo-political zones of Nigeria could profitably produce at larger industrial scales when the Cluster Programme is fully implemented The subcategory of projects here are as follows, and specific projects are listed in Table 5.

- Projects that will increase the share of the manufacturing sector in the Nigerian GDP from 4 to 40% by 2030
- Projects to support space travel by Nigerian astronauts to install 3 more Nigerian satellites and improvement of the Cyber-infrastructure to support S&T-based entrepreneurship
- Projects to improve financing of large-scale integrated science and entrepreneurship

As discussed by Balogun (150), investment in infrastructure will improve STI productivity and vice versa. The infrastructure required cuts across many sectors of the Nigerian economy.

3.3. Research and Development Intensification

FMST maintains a large network of research centers and institutes. Research and development (R&D) is listed in the categories of NSTIR 2030 programmes in Table 5 without details. The subcategories of NSTIR 2030 research programmes and projects, as well as their utilities and linkages to technologies for Nigerian economy diversification. The detailed list of research projects that satisfy the National Science, Technology and Innovation Policy of Nigeria, as well as NSTIR strategic objectives, are listed in Table 10. In the later table, each research programme comprises a set of projects ranging in duration from 2 to about 8 years. In assigning projects to the various FMST centers/institutes to lead, the following factors were considered.

- The mandate of the center/institute concerned
- The historical and current intellectual strength of the organization on the issue and associated subject matter
- The existence of a continuing project that the organization needs to extend to maximize benefits to Nigeria's STI and dependent economy
- The criticality of the focus issue and the capacity of the organization to rapidly build relevant expertise if it does not currently exist within the organization.

As discussed in the preceding chapter, the categorization of research issues do not match the exact separation lines that have existed for decades but reflect what is needed to drive Nigeria's STI to attainment of NSTIR 2030 goals. The past and current research programme configurations do not necessarily have to be maintained for the next 14 years. The specific research project categories, most of which are similar to existing disciplinary focus areas of the FMST research establishment, are:

- Biotechnology, including Pharmacology
- Health and Nutrition
- Environment, Meteorology and Water Resources
- Facilities and Networked Systems
- Renewable Energy Systems and Photonics
- Material Science, including Nanotechnology
- Mathematics, Computational and Communication Systems

- Space and Geospatial Systems
- Artificial Intelligence and Robotics
- Science Communication and Technology Diffusion

For each catalogued project under the categories listed above, the lead FMST centers/Institutes are identified and stated in bold while other potential collaborators within and/or outside the Federal Governments' research enterprise are also listed but not in bold letters.

Most of the research objectives presented in each knowledge sector below derive from Nigeria's national Policy on STI (11) with some mergers of objectives to reflect the issue categories and support disciplines presented herein. Attention must also be paid to Appendix 1 in which the utilities of these NSTIR 2030 research programmes to integrated and sectoral development plans in Nigeria are indicated.

3.3.1. Biotechnology including Pharmacology

The goals of research in this knowledge sector as described in the STI policy of the Federal Republic of Nigeria (11) are presented below verbatim.

i. Promoting the understanding of biotechnology and its applications in national development.

ii. Building capacity and capabilities in biotechnology research and its applications.

iii. Harnessing indigenous knowledge on natural products and commercializing discoveries, as well as positioning Nigeria in the market.

iv. Ensuring growth and opportunities in the application of advanced bio-processing and bio-manufacturing processes.

v. Facilitating brand recognition for Nigerian biotechnology products and benchmarking of progress.

vi. Promoting the documentation and use of bio-genetic resources and elimination of bio-piracy.

vii. Ensuring compliance with biosafety and bioethics guidelines in biotechnology R&D.

The research programme planned has great utility to Nigerian agriculture and manufacturing. Nigeria is very rich in botanical resources. Following many years of research, many flora and fauna have been discovered, identified and classified. There is a rich library of crop varieties (192) and medicinal plants (76) that can be the focus of deeper biotechnological research and development efforts to serve industrial and other socio-economic interests. Presently (199), about 72% of Nigeria's fruits and vegetable perish before consumption due to lack of processing. In order to illustrate the significance bio-preservation methods, an official of the Agricultural Fresh Produce Growers and Exporters Association of Nigeria (AFPGEAN) has observed (199) that although Nigeria has about 5 times more arable land than Kenya, Kenya earned about US$1 billion in fresh product exports to European markets annually while Nigeria struggles to earn just US$ 10 million annually. Biotechnological research can improve food preservation as well as the quality of processed materials. A related issue is the sourcing and improvement of agricultural raw materials to support agro-allied industries in Nigeria. Recently, one of the largest brewers in the world initiated plans (119) to establish breweries that will use domestic crops such as sorghum and cassava as raw materials. This will boost production of those crops with socio-economic benefits to farmers.

Biotechnology also offers tremendous opportunity for diversification of Nigeria's economy into the high-revenue sector of pharmaceutics. The range of possibilities in this regard is illustrated in Figures 20-25. Many medicinal plants have been identified in Nigeria. An example of a compendium published on such plants is the ***"Medicinal Plants of Nigeria-South-East Nigeria, Volume 1, published in 2008 by FMST's Natural Medicine Development Agency with the support of the Raw Materials Research and Development Council (RMRDC) (76)".*** Many advanced techniques need to be employed to evaluate Nigeria's herbal products as planned by the Federal Government through NIPRD (120); address the growing threat of resistance to antibiotics (145); and develop drugs that can address ailments that are common in Nigeria. With respect to the latter, anti-malarial drugs are a priority.

Drug prices have increased significantly in Nigeria as reported (156). As a result, many fake drugs are being manufactured and distributed. The development of genuine pharmaceutical firms in Nigeria

which will only be possible through research and development in pharmacology, is the long-term solution to this problem. It is commendable that the 2017 National Health Policy promotes the manufacture of medicines in Nigeria.

3.3.2. *Health and Nutrition*

Many health policies and programmes have been developed in Nigeria. Among them are the 2016 National Health Plan Policy (223), National Health Management Information System (138) and the National Strategic Framework on the Health and Development of Adolescents and Young People in Nigeria (144). These policies and programmes need to be intensified, not just at FMST research institutes but universities and hospitals as well.

i. Ensuring that research priorities are targeted towards meeting health and nutritional requirements and challenges in Nigeria.

ii. Promoting effective linkages and collaborations among knowledge institutions and industries engaged in health sector.

iii. Strengthening demand-driven R&D in natural and orthodox medicines as well as pharmaceutical research.

iv. Facilitating the development of biological diagnostic tools, vaccines and encourage R&D in alternative and molecular medicine as well as genomics.

v. Developing standards for monitoring and evaluation of health products.

vi. Promoting ethics and standards in research

vii. Promoting documentation and dissemination of natural health research

- **Youth Sports and Tourism**

In addition to research objectives on traditional health maintenance, there is also focus on youth, sports and tourism. Research on these aspects can also be considered to be of utility to both individual and community health. The objectives are as follows.

i. Encouraging R&D in sports medicine and materials, psychology, nutrition, physical education and other disciplines for the able-bodied and physically challenged.

ii. Promoting STI in recreational activities to enhance healthier and physically strong citizenry.

iii. Promoting competition and award schemes in STI among youth in and outside the educational system.

iv. Facilitating programmes and schemes for mentoring the youth in career development in STI.

v. Encouraging application of STI in tourism development.

vi. Incorporating STI into sports education

vii. Ensuring the development of appropriate curricula to enable the acquisition and application of appropriate R&D skills in regular universities, particularly Universities of Technology and Polytechnics.

viii. Developing sports infrastructure using STI.

ix. Collaborating and harmonizing STI operations in the sub-sector with relevant government ministries, agencies as well as the private sector.

x. Fostering collaboration between STI agencies and appropriate tourism and sports bodies.

3.3.3. *Environment, Meteorology and Water Resources*

Nigeria's environmental challenges are summarized in Figure 26 and illustrated in Figures 27-35. They vary from desertification in the North through air pollution in the West, erosion in the South East/Central Region and Southern Coastal Areas, to massive oil pollution in the Niger Delta. Inyang (57) has provided a comprehensive and illustrated analysis of Nigeria's environmental challenges and ways of addressing them. Superimposed on these ravages are ecological damages that are likely to intensify with increase in industrial activities and global climate change if both mitigative and adaptation measures are not developed and implemented. To illustrate the scale of socio-economic ravages that

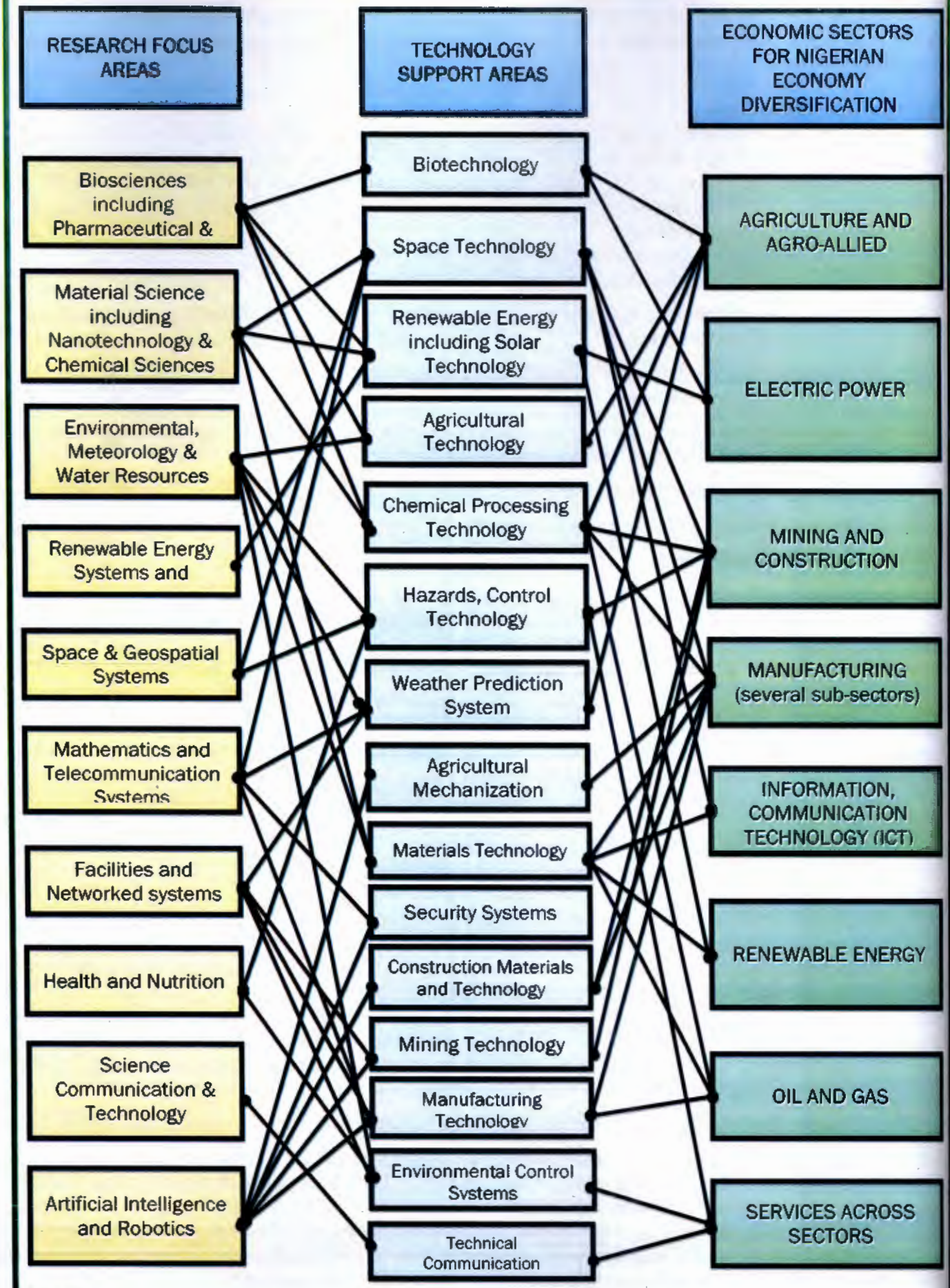


FIGURE 17: LINKAGES OF NSTIR 2030 RESEARCH FOCUS AREAS TO TECHNOLOGY IMPROVEMENT SECTOR VARIOUS INDUSTRIAL SECTORS OF NIGERIA

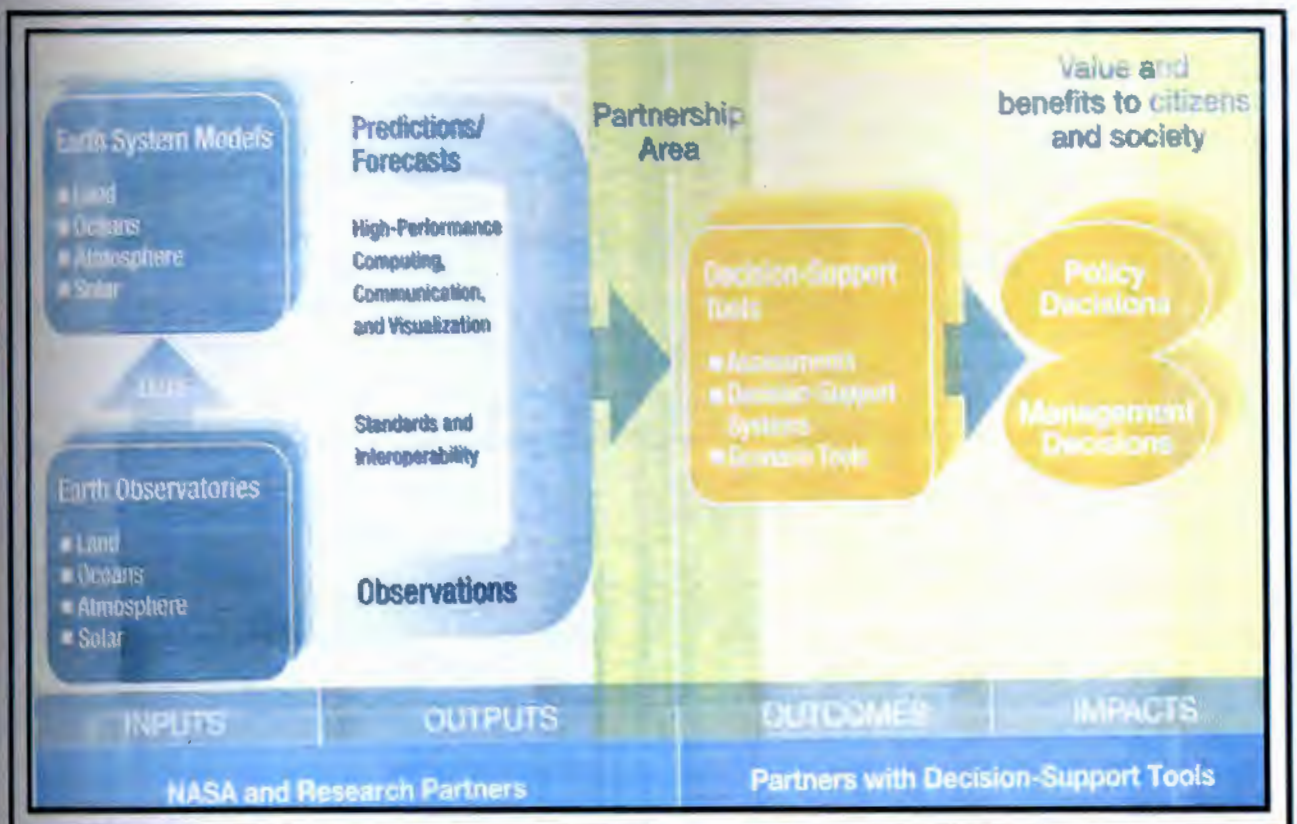


FIGURE 18: AN ANALYTICAL FRAMEWORK PROPOSED BY THE NATIONAL AERONAUTICAL AND SPACE ADMINISTRATION OF THE UNITED STATES FOR ACQUISITION AND USE OF ENVIRONMENTAL DATA FOR SOCIETAL BENEFITS (203)

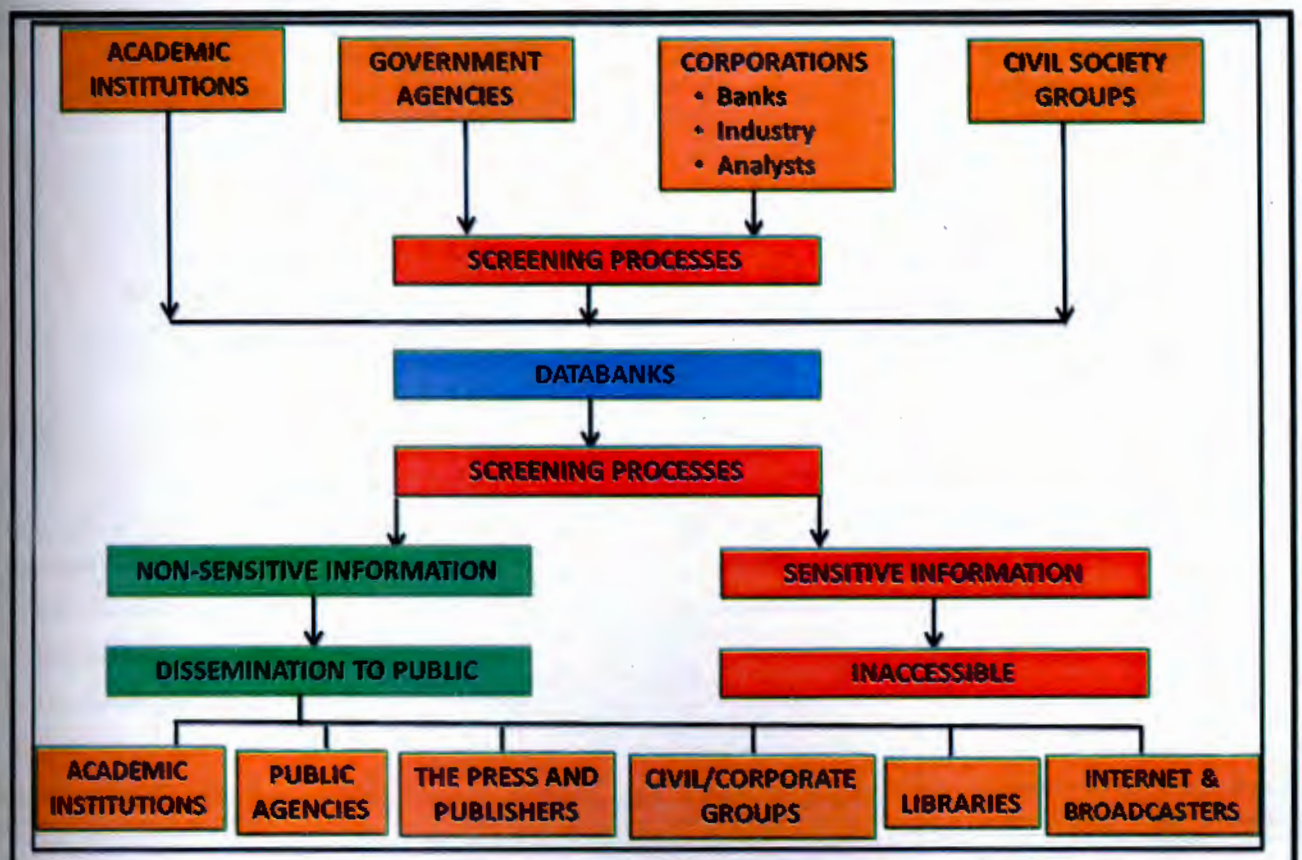


FIGURE 19: CONFIGURATION OF INFORMATION GENERATION, STORAGE AND ACCESS SYSTEMS THAT CAN BENEFIT CLIMATE CHANGE IMPACTS MANAGEMENT PROGRAMMES. INYANG (206)

a) ROLE OF STATE GOVERNMENTS
- Ensure access to land and mobilization of SME operators.
- Provision of rural infrastructure
- Co-ordination of data collection and information management
- Facilitating provision of soft loans/ Credit Guarantee.
- Provision of Common Facilities (CF)
- Provision of revolving funds for such ventures through Venture Capital
- Companies
- Promotion of SME products

b) ROLE OF FINANCIAL INSTITUTIONS
- Development Banks: CBN, BoA, Infrastructure Bank, NEXIM etc.-provision of soft loans and advisory services.
- Commercial Banks: Large scale banks, Community Banks, etc. to provide loans and training and advisory services.

c) ROLE OF LOCAL GOVERNMENTS
- Provision of rural infrastructure- roads, portable water supply etc.
- Mobilization of raw materials producers for accelerated production through co-operatives
- Co-ordination of data collection at the primary (ward) level
- Provision of land for new entrants
- Provision of access road to site
- Provision of security for the project site
- Promotion of SME Cluster products through trade fairs creation of markets.
- Funding assistance to SMEs

d) ROLE OF PRIVATE SECTOR (SMES)
- Promoters and operators.
- Provision of machinery.
- Provision of manpower.
- Provision of materials (industrial inputs)
- Provision of expertise.
- Monitoring and evaluation.
- Quality control of products
- Management of data on the cluster.
- Large industries to support small ones through guaranteed market for intermediate raw materials to be produced.

e) ROLE OF STI INSTITUTIONS
- Develop and deploy innovations and technologies. All agencies of the FMST and indeed others outside the Ministry should be involved.
- Adopt or establish clusters as avenues for commercialization of research findings. Every University and research institute to establish a cluster on commercial basis in collaboration with other stake holders.
- Generation and dissemination of knowledge through seminars, training,

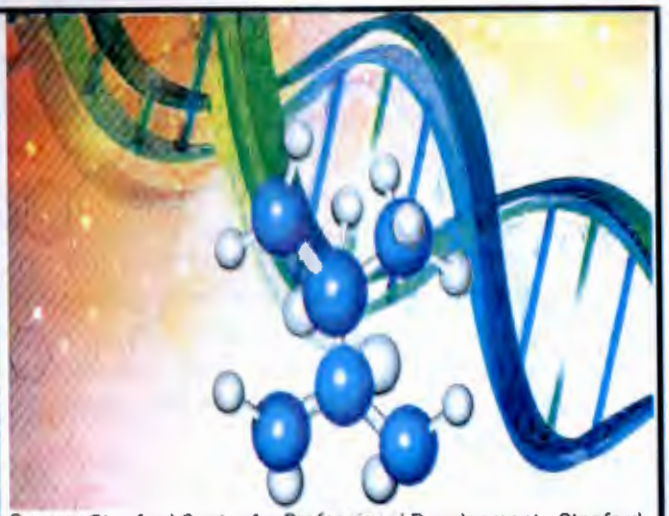
f) ROLE OF FEDERAL GOVERNMENT
- Policies to facilitate cluster development.
- Setting standards for cluster practice.
- Facilitating provision of infrastructural facilities e.g. roads, power, water and buildings, ICT for networking linkages
- Provision of revolving fund for ventures.
- Promotion/marketing of SME products.
- Favorable tariff regime for SME products.
- Provision of SMEs data and Information Management System.
- Setting quality standards and control for SMEs products.

TABLE 12: REGIONAL SPECIALIZATION IN RESPECT TO INDUSTRIAL PROSPECTS IN NIGERIA (198)

S/NO	REGION	PRODUCTS
1	North East	Processed minerals, ethanol, biodiesel, cement, fruit juices
2	North West	Processed meat, leather goods, biofuels
3	North Central	Cut granite, furniture, processed cotton fabrics
4	South East	Over the counter drugs, leather goods, garments, palm oil
5	South West	Plastics, garments, general goods
6	South South	Petrochemicals (refined oil), fertilizers, plastics, oil services

Source: YourArticleLibrary.com

FIGURE 20: SOME BIOTECHNOLOGY APPLICATIONS IN THE HEALTH AND AGRICULTURAL SECTORS

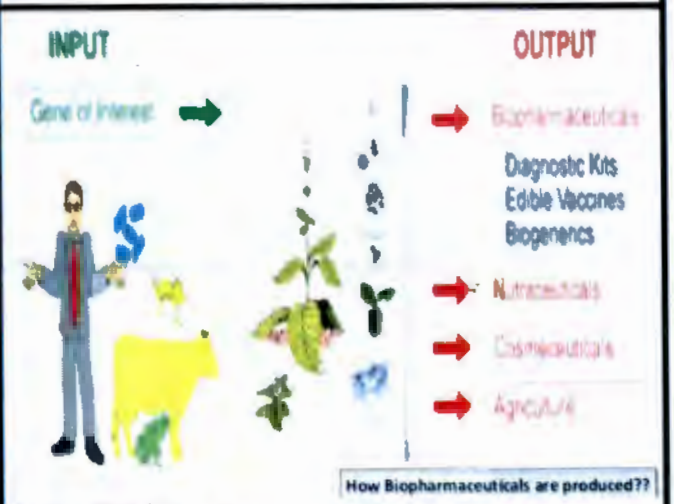


Source: Stanford Center for Professional Development - Stanford University

FIGURE 21: DNA RESEARCH IS NECESSARY FOR ADVANCES IN HEALTH AND AGRICULTURAL SYSTEMS

Source: Hotcourses Abroad

FIGURE 22: PLANT CULTURING TO SUPPORT AGRICULTURE



Source: SlideShare

FIGURE 23: GIN ANALYSIS IN SUPPORT OF FOOD PRODUCTION

Source: NaijaGists.com

FIGURE 24: DRUG MANUFACTURE USING ADVANCES IN BIOTECHNOLOGY

Source: Merlo Farming Group

FIGURE 25: PLANT BREEDING APPLICATION IN BIOTECHNOLOGY

environmental phenomena can cause in society, Nigeria's National Emergency Management Agency (NEMA) estimated (155) that in 2010, about 500,000 people were displaced by floods in Nigeria. A fair proportion of such measures must be locally developed to enhance the sustainability of improvements.

Damages to the environment and their impacts on human and ecological health are significant at all scales, from microscopic to macroscopic and require creation and deployment of knowledge from numerous disciplines. Inyang (2008) has briefly discussed the dependence of observation-based conclusions about environmental matters on the thermodynamics and kinetics of environmental processes, most of which need to be investigated by the Nigerian research establishment. Such investigations are needed to assess exposures to air pollutants in cities like Lagos, Kano, Onitsha and Port Harcourt in ways that have been done elsewhere (213); develop materials for clean-up and containment of wastes (211); monitor ecological changes; and understand/predict weather patterns to serve air transport safety programmes, and aid farmers across Nigeria. The specific research objectives in this suite of inter-related disciplines as contained in Nigeria's STI Policy, are as follows.

- **Environmental Science and Technology**
  i. Promoting the integration of environmental concerns into all development policies and ensuring public understanding of the scientific basis of their actions on the environment
  ii. Developing an appropriate and effective waste management system to reduce pollution emission from waste generation.
  iii. Encouraging the use of clean technologies in production systems.
  iv. Developing capacity to monitor, predict and mitigate adverse effects of natural phenomena such as floods, drought and desertification.
  v. Encouraging science and technology intervention that promotes sustainable development.
  vi. Encouraging integration of environmental factors with standard national accounts/assets to improve environmental monitoring systems.
  vii. Promoting the development of a national environmental database to support economic development.
- **Water Resources**
  i. Developing R&D, demonstration and deployment capabilities in the management of surface and ground water resources for sustainable exploitation
  ii. Promoting the use of safe, clean, efficient and sustainable water technologies for national development.
  iii. Promoting R&D in water conservation and utilization techniques for domestic, agricultural, energy and industrial use.
  iv. Facilitating the adaptation of appropriate water technologies for rural development.
  v. Developing capacity and capabilities for water management and environmental sustainability.

3.3.4. Facilities and Networked Systems

Nigeria needs to improve in infrastructure across all sectors of the economy. Infrastructure can be viewed as structures that are connected by services within a network. They need investment in knowledge to address planning, design, construction, operation, monitoring and maintenance. Research and development is essential to optimize designs and operations due to the very high budgets involved. As illustrated in Figures 36-41, targeted improvements in infrastructure within the NSTIR 2030 timeframe, cover smart electric power grid, transportation networks, housing, cable network, industrial facilities and ports. Engineering infrastructure also has to be developed to facilitate the use of novel techniques in nano-manufacturing, mechatronics, photonics and metrology among others, to improve Nigeria's industrial output and diversify the economy. The research objectives and functions in this field are as follows.

- **Transport System**
  i. Promoting R&D to support activities in the road, rail, water and aviation transportation system.
  ii. Encouraging investment in local innovation in the transport and aviation sectors.

iii. Facilitating the adoption and use of R&D outputs and local innovations for all forms of transportation and construction (i.e. road, rail, water and aviation).

iv. Conducting R&D activities in accident investigation and mitigation

v. Strengthening evolving mechanisms and strategies for information management system to establish and operate inter modal urban mass transport system.

vi. Facilitating R&D activities and innovations that will fast-track massive delivery of community-based technologies for rural / access roads construction and maintenance.

vii. Strengthening the STI component in the design, construction and maintenance of roads.

viii. Promoting the use of STI for efficient transport management for socio-economic and industrial development.

ix. Investigating potentials for expanded public transportation service and transit-oriented development to reduce transport emission while providing efficient mobility option.

x. Developing a quality-assured, web-based knowledge database on research capacities of tertiary institutions, transportation technology, and technology needs in transport industry in Nigeria.

xi. Encouraging research and development in technological devices for monitoring and tracking transport/traffic operations.

- **Works, Land, Housing and Urban Development**
  i. Establishing codes/standards and strengthen capacity for effective design, management and production of relevant technologies in building, construction and urban development

  ii. Defining the roles of federal, state, local governments and other stakeholders in dealing with issues of urban development, housing and land administration.

  iii. Promoting the application of STI in the production and utilization of local materials for building and construction to facilitate mass-housing delivery.

  iv. Promoting effective linkages and collaborations among knowledge-based institutions, professional bodies and the construction industries.

  v. Promoting R&D and innovative schemes for evolution of Green construction culture in Nigeria (Green homes and Green cement).

  vi. Encourage activities and regulatory roles that promote public safety in building and construction and mitigating effects of natural disasters.

  vii. Promoting the development standards for design, specifications and materials in building and construction.

  viii. Institutionalizing strategies for funding R&D activities in Building, Land and Urban development including extra-budgetary steps like duties and tariffs.

  ix. Establishing framework for ICT-based land administration and management of land ownership and mitigating effects of environmental disasters through best use of land and resources.

- **Industrial Research, Development and Production**
  i. Ensuring R&D activities are directed towards the development of appropriate technologies for the production of industrial goods and services in Small, Medium, and Large Scale firms.

  ii. Developing local capacity for design and production of machine tools and spare parts for rapid industrial growth and development.

  iii. Fostering interactions among universities, or higher education research institutions, industries and investors to generate innovations.

  iv. Ensuring value-addition to the nation's natural resources for industrial development.

  v. Fostering the development of technological entrepreneurs to facilitate innovation.

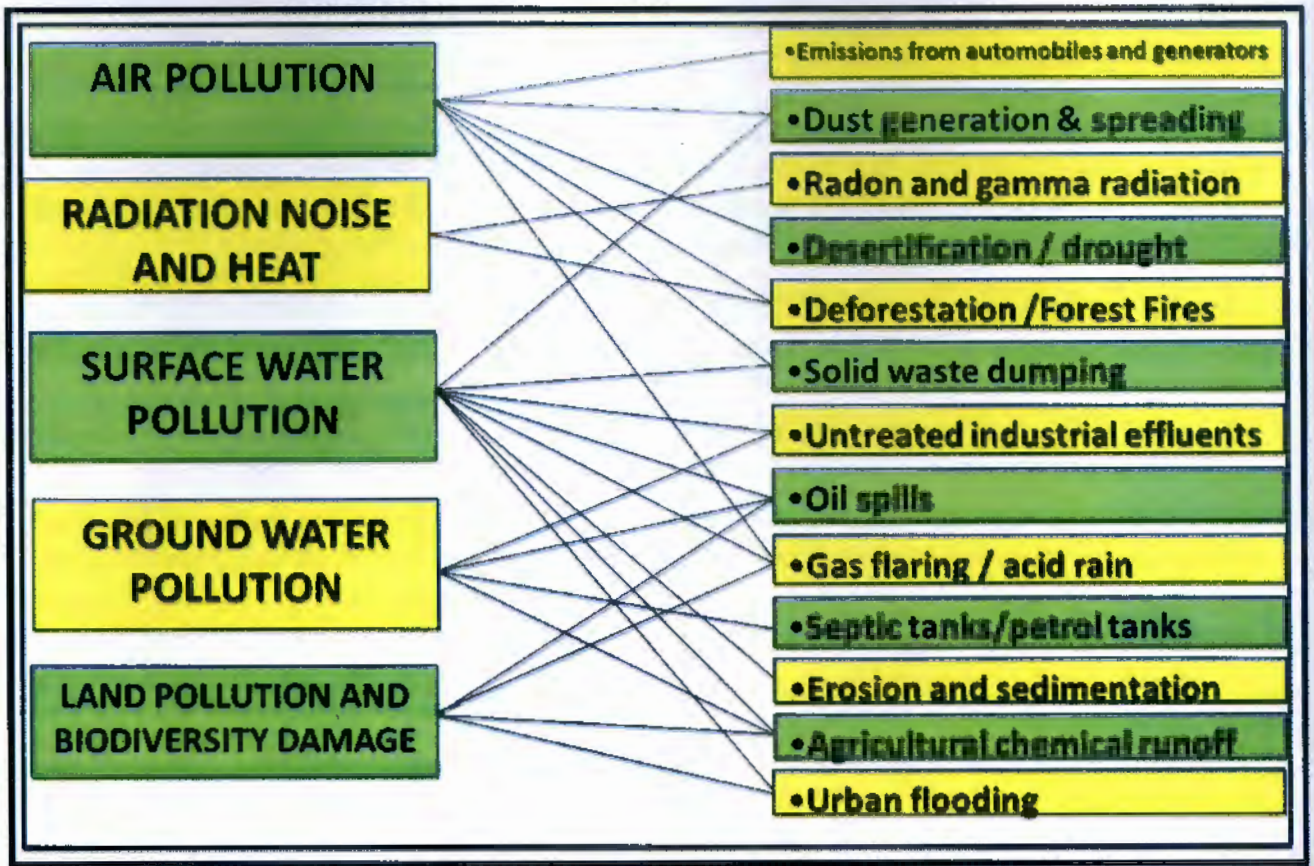


FIGURE 26: NIGERIA'S CONTINUOUS AND PERIODIC ENVIRONMENTAL HAZARDS THAT HAVE PRODUCED MAJOR DISASTERS (57)

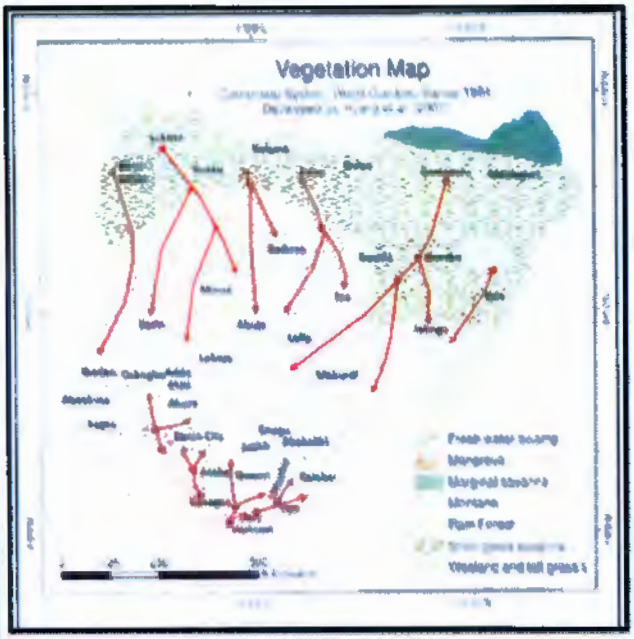


FIGURE 27: EXPECTED MIGRATION PATTERNS AS CLIMATE CHANGE IMPACTS AND SOCIAL INSECURITY DERIVE SEGMENTS OF NIGERIA'S POPULATION SOUTHWARD FROM DROUGHT-RAVAGED ZONES IN THE NORTH AND FROM FLOODED AREAS NORTHWARD FROM THE FAR SOUTH. (57)

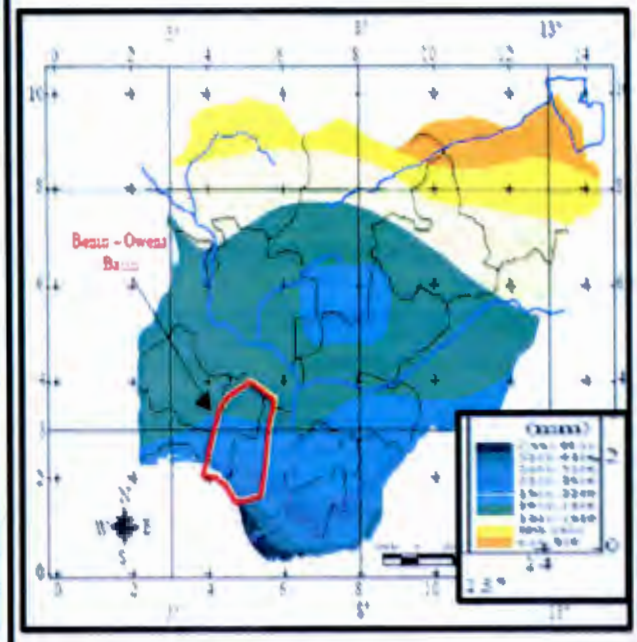
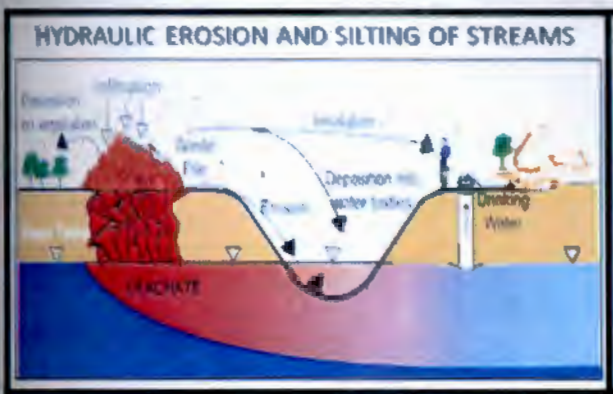


FIGURE 28: RAINFALL MAP OF NIGERIA WHICH ALIGNS WITH THE SOUTHWARD MOVING DESERTIFICATION FRONT THAT PARALLELS THE 1030-1400 MM ANNUAL RAINFALL FRONT (ADAPTED FROM A.O. AYENI, A.S.O. SONEYE, O.O. FASUNWON, R.T. MITEKU AND L.A. DJIOTANG-TCHOTCHOU. (57)



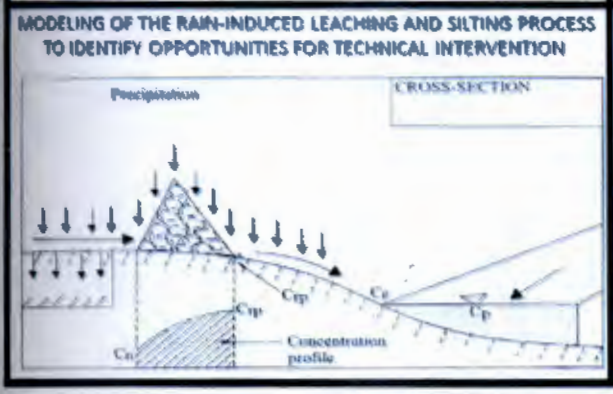
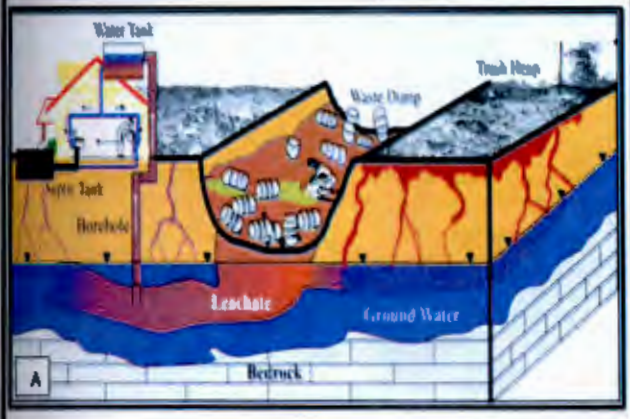
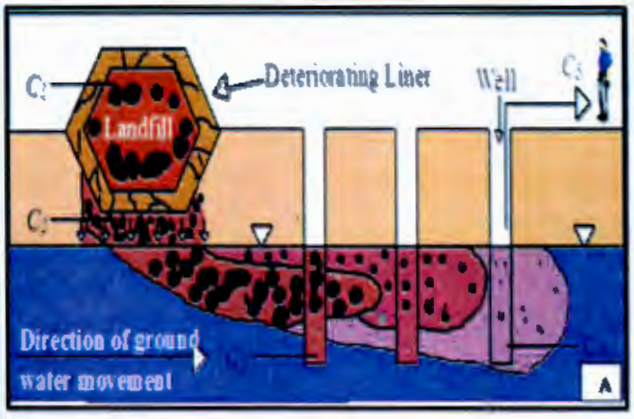


FIGURE 29: ENVIRONMENTAL AND WATER QUALITY DEGRADATION BY RUNOFF



Percent of population with treated water versus typhoid deaths in the United States, 1880-1980.

FIGURE 30A: (A) SCENARIO OF GROUND WATER POLLUTION BY A WASTE DUMP WITH IMPACT ON BOREHOLE WATER QUALITY, (B) TYPHOID HISTORY GRAPH OF THE UNITED STATES



$$C_4 = \frac{C_2}{F_d}\left[\sum_{i=1}^{n} A_i\right]^{n-1}$$

- F_d = Dilution factor which is in this formulation, a dimensionless fraction;
- A_i = Contaminant attenuation factor which is also a dimensionless fraction;
- C_1-C_3 = Contaminant concentrations at different locations (figure above);
- N = Number of soil compartments of distinct characteristics through which the contaminant travels

B

FIGURE 30B: (A) POORLY DESIGNED AND BUILT LANDFILL THAT LEAKS POLLUTANTS INTO GROUNDWATER ACCESSED BY BOREHOLES, (B) DISTANCE SCALING FACTORS FOR CONTAMINANT CONCENTRATION ESTIMATION

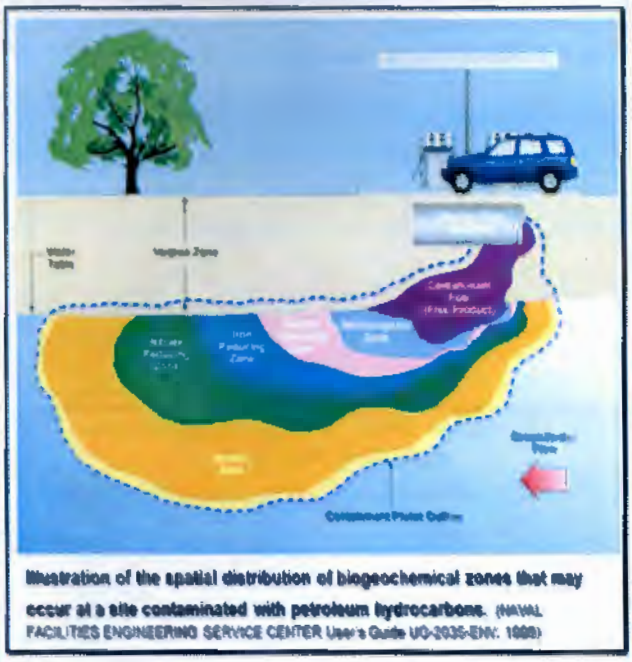


Illustration of the spatial distribution of biogeochemical zones that may occur at a site contaminated with petroleum hydrocarbons. (NAVAL FACILITIES ENGINEERING SERVICE CENTER User's Guide UG-2035-ENV, 1998)

FIGURE 31: POSSIBLY THOUSANDS OF BURIED UNDERGROUND TANKS FOR PETROL ARE LEAKING ALL OVER NIGERIA TO CONTAMINATE BOREHOLE WATER WITH KNOWN IMPACT ON HUMAN WITHOUT MONITORING AND MITIGATIVE ACTIONS

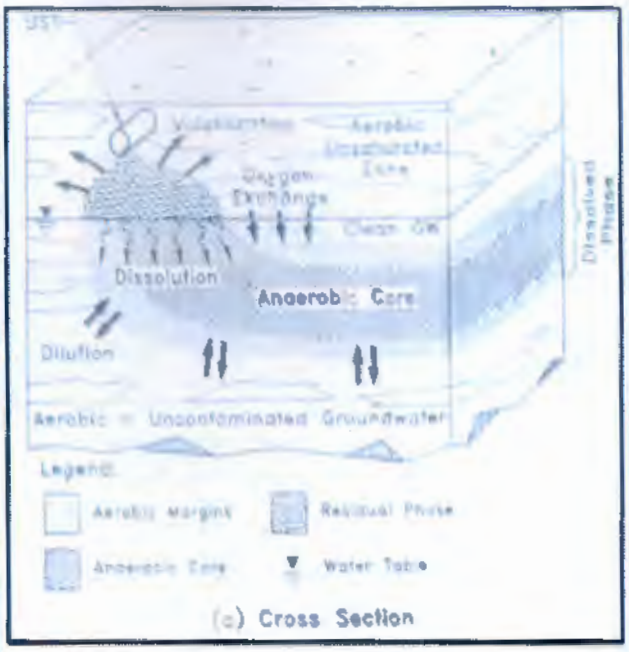


FIGURE 32: DEPICTION OF PETROLEUM PRODUCTS FATE AND TRANSPORT PROCESSES IN THE SUBSURFACE: SOME PROCESSES WILL BE ENHANCED BY HIGHER SOIL TEMPERATURE AND ELEVATION OF THE WATER TABLE IN NIGERIA DURING WET SEASONS

(a) DITCH EROSION DOWNSTREAM OF BYPASSED DITCH RELIEF CULVERT INLET. (Source: www.fs.fed.us)

(b) DESTRUCTIVE ACTION OF GULLY EROSION ON CROPS AND PLANTATIONS IN EASTERN NIGERIA

(c) EROSION OF CONTAMINATED GEOMATERIALS INTO A MINING POND IN ZAMFARA STATE, NIGERIA (Source: www.wsj.com)

(d) THREATS TO CONSTRUCTED FACILITIES BY GULLY EROSION IN EASTERN NIGERIA

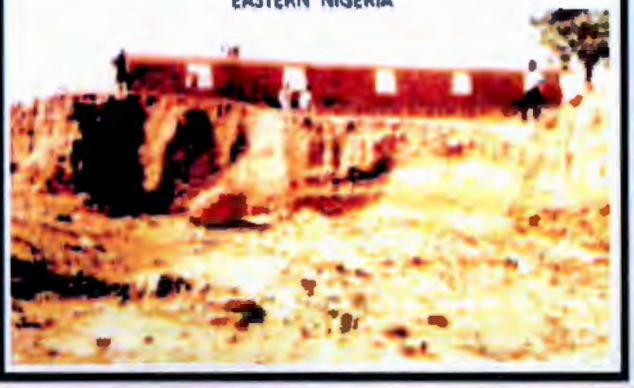


FIGURE 33: HYDRAULIC EROSION DAMAGES TO TERRAIN AND STRUCTURES

FIGURE 34: RESOURCE LOSSES, OCCUPATIONAL CHANGES, POLLUTION AND COMMUNAL CONFLICT FACTORS (SOME OF WHICH ARE PARTLY TIED TO CLIMATE CHANGE) THAT WILL ACCELERATE OUTWARD MIGRATION FROM PARTS OF THE NIGER DELTA

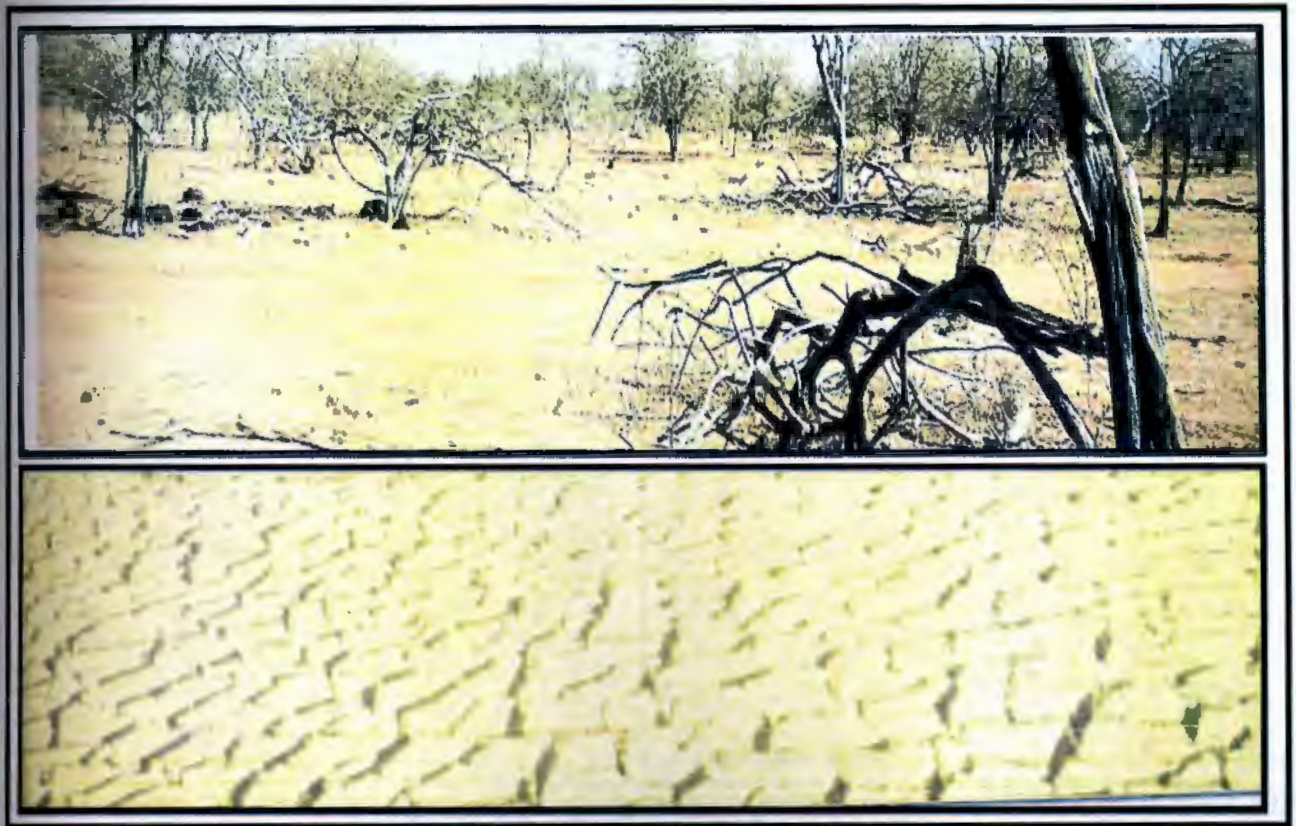


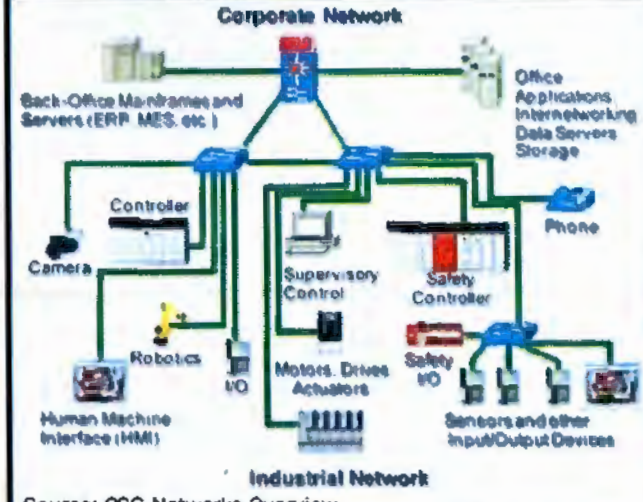
FIGURE 35: THE RAVAGES OF DESERTIFICATION OF SAHELIAN AFRICA HAVE ECOLOGICAL AND SOCIO-ECONOMIC IMPLICATIONS

Source: RTC Magazine

FIGURE 36: SMART GRID FOR ELECTRIC POWER SUPPLY AS A NETWORK FOR OPTIMIZATION

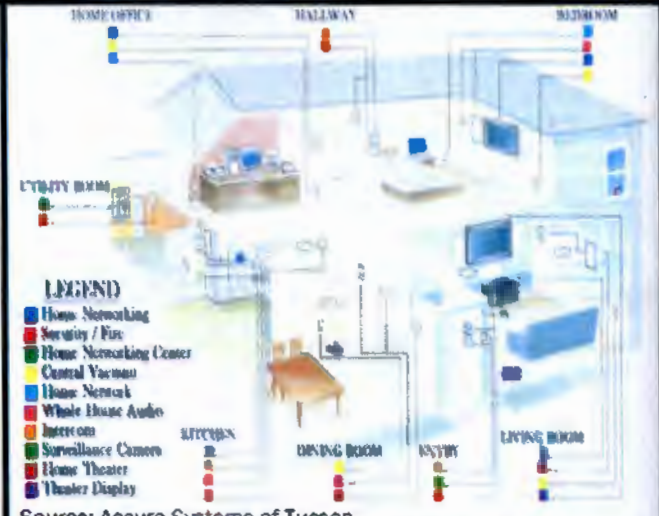
Source: Siba - News feed - Spatial Industries Business Association - SIBA

FIGURE 37: TRANSPORTATION NETWORK FOR DESIGN AND OPERATIONAL IMPROVEMENT



Source: CSG Networks Overview

FIGURE 38: BUSINESS NETWORKS THAT CAN BE IMPROVE THROUGH INNOVATIVE DESIGN

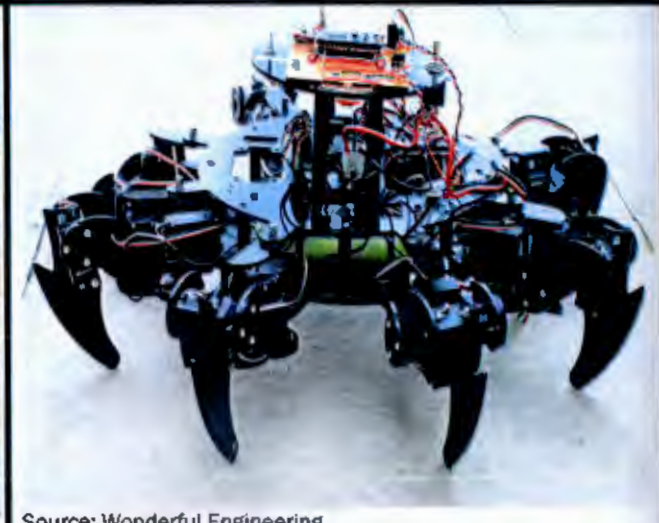


Source: Accura Systems of Tucson

FIGURE 39: SHELTER/HOUSING AS A STRUCTURAL AND FUNCTIONAL NETWORK FOR IMPROVEMENT

Source: The Blue Book

TABLE 40: CABLES NETWORKED FOR OPTIMAL OPERATION



Source: Wonderful Engineering

FIGURE 41: MECHATRONICS COMPOSITING MECHANICS, ELECTRONICS, MATHEMATICS AND COMPUTERS FOR INTELLIGENT OPERATIONS

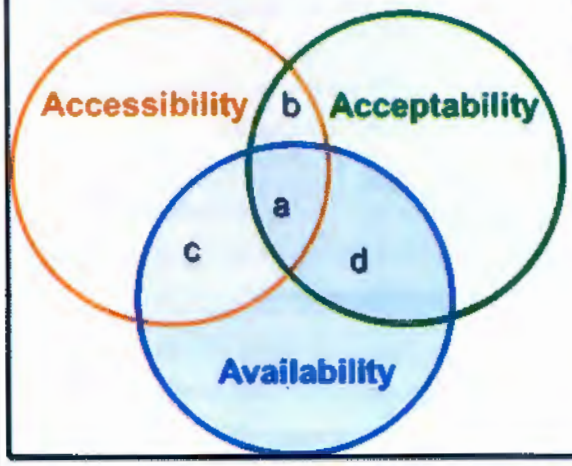
- **Science Laboratory Technology (SLT)**
  i. Facilitating the provision of minimum standard laboratories in secondary, tertiary and STI institutions for learning, teaching, services and Research & Development.
  ii. Supporting activities in the educational, research, medical and industrial laboratories.
  iii. Adopting and promote the principles of Good Laboratory Practice (GLP) in conformity to international best practice
  iv. Fostering training and employment of certified science technologists for proper management and maintenance of laboratories.
  v. **Developing and promoting the documentation of laboratory equipment's for planning and** development.
  vi. Ensuring the monitoring, inspection, accreditation and certification of laboratories in R&D institutions in both public and private sectors by relevant regulatory bodies.
- **Defence & National Security**
  i. Supporting and facilitating STI capacity and capability building in the operations of the armed forces and other security services.
  ii. Promoting strategic military R&D for national security and development.
  iii. Encouraging the development and deployment of advanced technologies in military hardware and operations through reverse engineering.
  iv. Promoting the use of STI to prevent and control crimes and threats to national security.
  v. Deploying STI for the protection and security of indigenous technology, innovation and related intellectual property.
  vi. Establishing a Corps of STI intelligence officers in the NIA/Foreign Affairs.
  vii. **Establishing an STI "Desk" in the office of the National Security Adviser (NSA) for** protection of indigenous technology.
  viii. Fostering linkages of R&D collaborations among the academia, military, industries/businesses for the benefit of National military industrial complex.
  ix. Encouraging the sourcing of about 5% of military hard and software locally.

3.3.5. *Sustainable Energy Development*

Energy is the enabler of economic development. Nigeria has many energy sources that have not been **significantly exploited. Alams and Ozuzu (200) have given a very good summary of Nigeria's energy** security milestones and the tasks that are required to improve circumstances. Energy in this regard is **partitioned into fuels (oil and gas) and electric power resources. Nigeria's electric power, and oil and gas** plans call for an increase in renewable energy systems in the energy mix, and improvement in the downstream **capacities of Nigeria's oil and gas industry. Any energy mix that Nigeria adopts must have** the triple characteristics of availability, accessibility and acceptability illustrated in Figure 42 (21). Acceptability pertains to sustainability-the parameter that has driven many countries including Nigeria, to seek an increase in the proportion of renewable energy systems in the energy mix. Figure 43 shows the projected percentages of renewable energy in energy mixes of various countries by 2030, using current **resources and capacities (139). Nigeria's percentage is a meagre 2%. It needs to be at least** 20%. To attain that, much has to be done on research, development and entrepreneurship. The International Renewable Energy Agency (IRENA) (139) has developed a roadmap on renewable energy-technology deployment that is also relevant to Nigeria.

Nigeria has committed to some mitigative actions on global climate change. Among the commitments stated in its Intended Nationally Determined Contribution (INDC) (see Table 13), are: ending of gas flaring by 2030, achieving off-grid solar photovoltaic capacity of 13GigaWatts, improvement in electricity grid, shifts in transportation from cars to buses to improve energy efficiency which it intends to increase by 30% by 2030, and deployment of efficient gas generators. Inyang (203) has developed Figure 44 as the catalog of techniques including research, that need to be utilized more

1. **Energy Availability:** Continuous availability of reliable and efficient energy
2. **Energy Accessibility:** Affordability of reliable energy services for which payment is made
3. **Energy Acceptability:** amenability of the energy sources to be produced, transmitted, and used in ways that preserve the environment and gain public acceptance



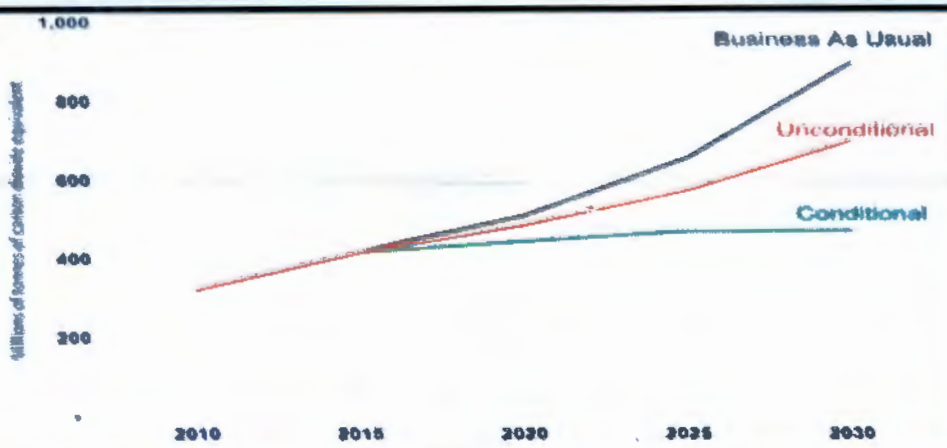
a. Excellent market prospects
b. Very good market prospects
c. Fair market prospects
d. Low market prospects

FIGURE 42: THE UTILITY AND SUSTAINABILITY OF ALL ENERGY SOURCES SHOULD BE DETERMINED THROUGH THE USE OF THREE CRITERIA (214)

Note: Percentage indicates how much renewable energy each country consumes in 2030 if the Remap Options are deployed
Source: (Reference no. 139), Roadmap for A Renewable Future, IRENA (2016)

FIGURE 43: COUNTRY OPPORTUNITY VARY, BUT EACH COUNTRY HAS A ROLE TO PLAY IN SCALING UP RENEWABLES

TABLE 13: SUMMARY OF KEY ASPECTS OF NIGERIA'S INTENDED NATIONALLY DETERMINED CONTRIBUTION (INDC)

Aspect	Detail
Type of objective	Reduction from Business as Usual (BAU)
Target year	2030
Implementation Period	2015-2030
Base data period	2010-2014
Summary of objective	Economic and social development: grow economy 5% per year, improve standard of living, electricity access for all
Unconditional and conditional mitigation objectives	20% unconditional, 45% conditional
Key measures	• Work towards ending gas flaring by 2030 • Work towards Off-grid solar PV of 13GW (13,000MW) • Efficient gas generators • 2% per year energy efficiency (30% by 2030) • Transport shift car to bus • Improve electricity grid • Climate smart agriculture and reforestation 1,000
Trajectory [update figure once agreed]	
Emissions per US$ (real) GDP	0.873 kg C02e (2015) [0.491 kg C02e (2030)]
GDP per capita (US$)	2,950 (2014) 3,964 (2030; real 2015 US$)
Estimated emissions per capita	Current: around 2 tonnes C02e 2030 BAU: around 3.4 tonnes C02e 2030 Conditional: around 2 tonnes C02e
Global Warming Potentials used	IPCC Fourth Assessment Report
Cost Estimate Data	National Cost = $142b; National Benefits = $304b (World Bank report "Low Carbon Development Opportunities for Nigeria" (2013))
Gases covered	CO_2, N_2O, CH_4
Emissions as % of global total	<1% (2010)
Historical emissions (1850-2010)	2,564.02 million tonnes

effectively to address global climate change in Nigeria and other countries. Nigeria's STI research objectives on energy systems in general (including renewable energy), are stated below.

i. Developing R&D, demonstration and deployment capabilities in thermal (coal, oil and gas), nuclear, solar, wind, biofuels, hydro and other renewable energies.

ii. Promoting the use of safe, clean, efficient and sustainable energy technologies for national development.

iii. Encouraging the development of energy conversion technologies for sustainable power generation.

iv. Facilitating the adaptation of appropriate energy technologies for rural development.

v. Encouraging the development and deployment of locally produced power equipment for sustainable power industry.

vi. Supporting national vision to acquire technologies for sustainable power industry.

3.3.6. *Material Science, Including Nanotechnology*

Paraphrasing Inyang (210), "economic growth has been driven by the use of large quantities of materials such as stone, soil metals, biomass, coal, petroleum, plastics and ceramics". "The availability, beneficiation and flow of raw and processed materials vary among countries and are the determinants of economic advantages that may accrue to well-planned economies". Recognition of this circumstance by the Federal Government of Nigeria led to the creation of Nigeria's Raw Materials Development Research Council (RMRDC). It is important to appreciate the diversity and extensiveness of use of materials by society as depicted in Figures 45-50. The flow of raw materials in society has been categorized as follows by Inyang (210).

i. Domestic process output (DPO): total quantity of materials used in the domestic economy that is derived through domestic extraction and/or import from other countries;

ii. Domestic hidden flows (DHF): total quantity of materials mobilized domestically during the provision of economic commodities without entry of the materials themselves into the domestic economy;

iii. Total domestic output (TDO): sum of DPO and DHF, which amounts to the total quantity of materials used in the domestic economy, including wastes;

iv. Gateway flows (GF): component of TDO or DPO that escapes from the economy into the air, land, and water. Secondary deposition is not included in GF;

v. Sector flows (SF): component of TDO or DPO that is pertinent to activities nested in individual economic sectors, such as construction, energy, transportation, and agriculture;

vi. Dissipative flows (DF): quantity of materials deliberately spread into the environment as a consequence or in association with material use; and

vii. New additions to stock (NAS): quantity of new materials from technological advances used in construction and manufacture of goods as replacements for traditional materials

In 2015, mining contributed approximately 0.33% of the GDP of Nigeria which was much less than the 4-5% achieved in the 1960s-1970s period (164). Nigeria has developed a Roadmap for the Growth and Development of the Nigerian Mining Industry (2016) (164) which includes ***"Improving the quality and breath of geo-scientific data gathered in a cost-efficient manner"***. The development, adaptation and use of existing and new materials are essential to Nigeria's industrialization efforts. Materials like cement, polymers and clays mined or synthesized, need to be produced at lower costs to fulfill application needs in industrial processes (106) and construction (105, 107, 211). The STI objectives are stated below.

- **Mines and Materials Development**

i. Encouraging R&D in the exploration, exploitation, utilization and value addition of mineral resources.

ii. Building capacity and enhancing capability in solid minerals processing technologies and new materials development.

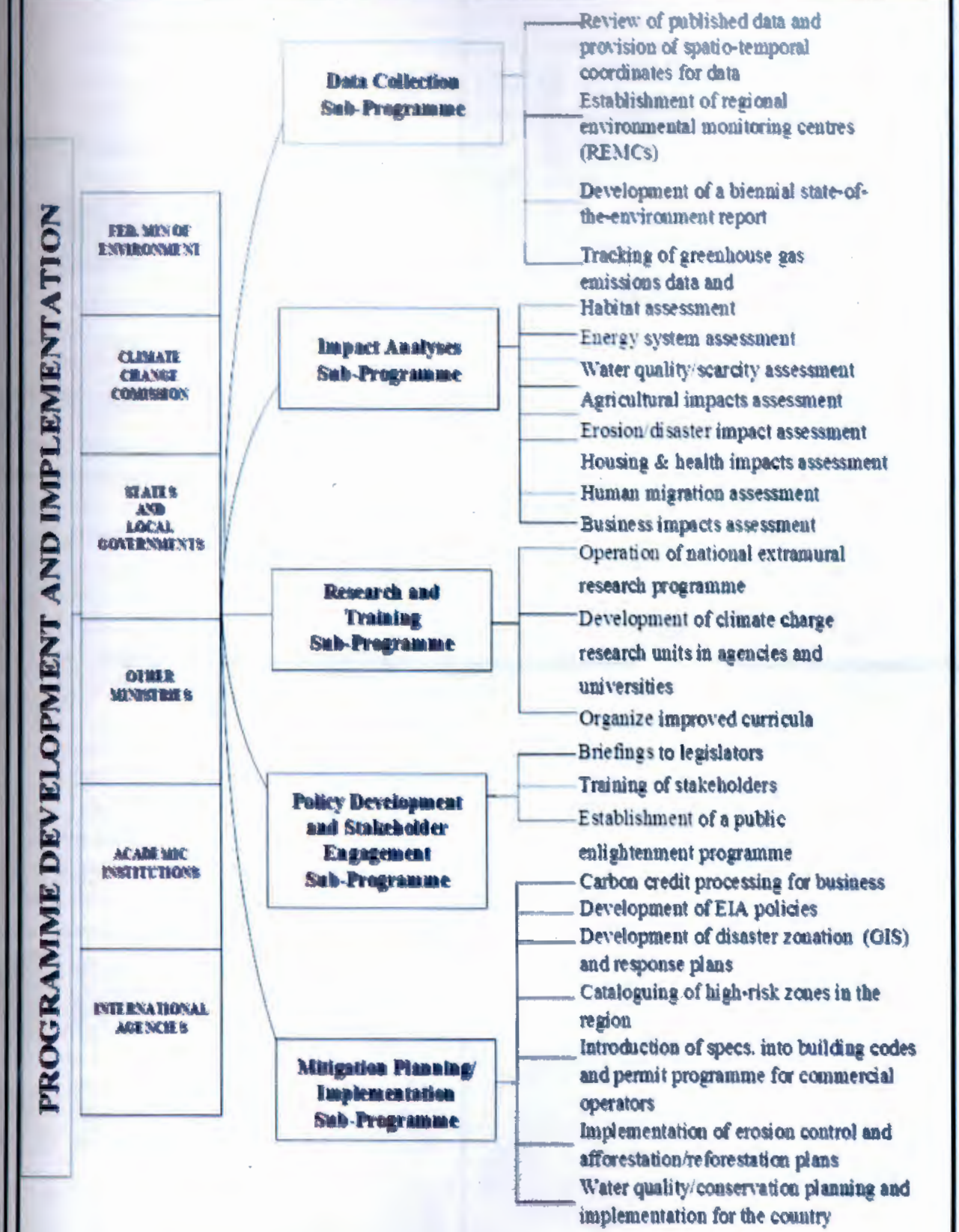
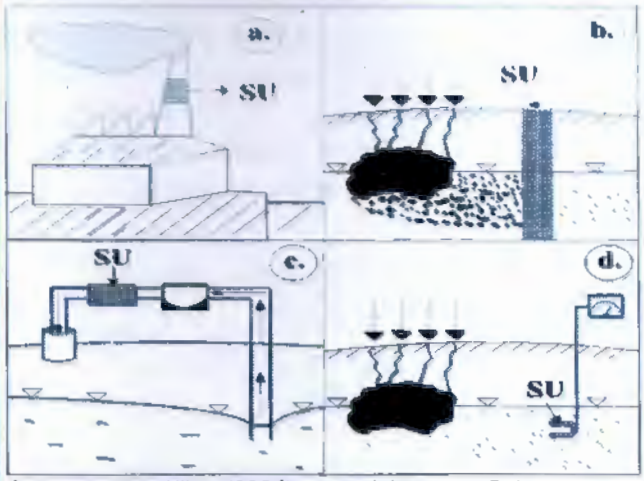


FIGURE 44: ELEMENTS OF GLOBAL CLIMATE CHANGE RISK ANALYSES AND IMPACTS MITIGATION PLAN PROPOSED FOR IMPLEMENTATION IN NIGERIA. INYANG 2011 (203)



Source: Inyang, Hilary (2004) research lecture at Duke University, North Carolina, USA

FIGURE 45: APPLICATIONS OF MATERIALS AS SORBENTS IN CIVIL, ENVIRONMENTAL AND INDUSTRIAL OPERATIONS

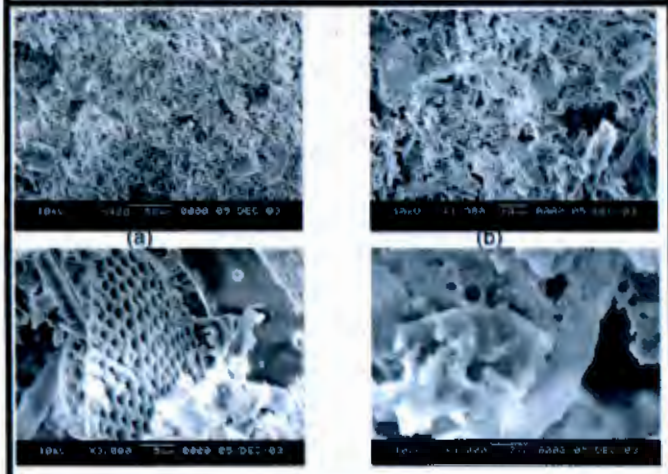
$$\delta_u \alpha \delta_u$$

$$\delta_u = \gamma \cdot \delta_u$$

- δ_u = the work required to bring molecules from solution to create new surfaces on solids or in pore space
- δ_u = the size of the area created
- = the surface energy (or interfacial tension) in units of Jm^{-2} or Nm^{-1}

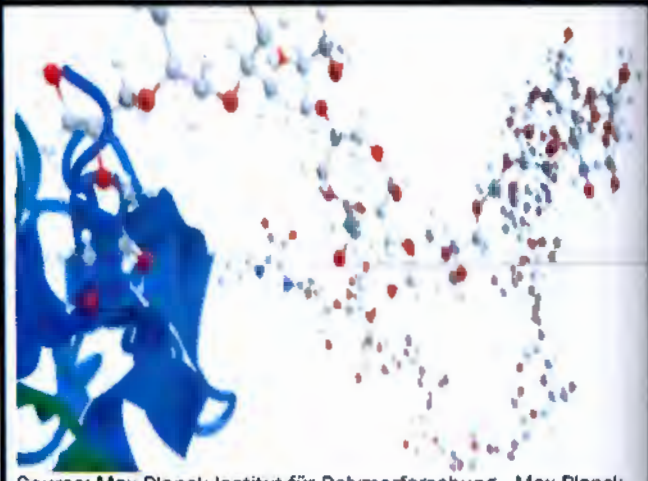
Source: Inyang, Hilary (2004) research lecture at Duke University, North Carolina, USA

FIGURE 46: FUNDAMENTAL INVESTIGATIONS OF THE ROLE OF SURFACE ENERGY IN THE INTERACTION OF MATERIALS FOR APPLICATIONS IN INDUSTRIAL AND CIVIL PROCESSES



Source: Inyang, Hilary (2004) research lecture at Duke University, North Carolina, USA

FIGURE 47: MICROSTRUCTURAL ANALYSES OF BYPRODUCTS, REFRACTORIES AND WASTES FOR LARGE-SCALE RECYCLING

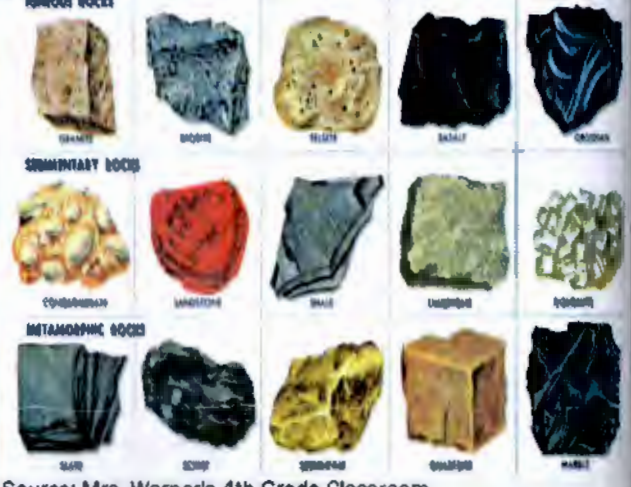


Source: Max-Planck-Institut für Polymerforschung - Max-Planck-Gesellschaft

FIGURE 48: SYNTHESIS, ANALYSES AND FABRICATION OF POLYMERS FROM NATURAL MATERIALS FOR CIVIL AND INDUSTRIAL OPERATIONS

Source: NDT Resource Center

FIGURE 49: ANALYSES OF METALS AND NANO MATERIALS FOR ADVANCED TECHNOLOGICAL, CIVIL AND INDUSTRIAL OPERATIONS



Source: Mrs. Warner's 4th Grade Classroom

FIGURE 50: ANALYSIS OF MINERALS AND ROCKS FOR CIVIL, INDUSTRIAL AND MEDICAL APPLICATIONS

iii. Strengthening the development and transfer of technologies for sustainable utilization of mineral resources.

- **New and Emerging Technologies (Nanotechnologies and New Materials)**
  i. Building institutional capacity and capabilities in new and emerging technologies.
  ii. Encouraging collaborative R&D activities between industry, higher education and research institutions on new and emerging technologies. (external collaborations)
- **Raw Materials and Manufacturing**
  i. Developing capacities in storage, retrieval and updating of data and information on earth-based raw materials.
  ii. Promoting access to, and stimulating interest on, earth-based raw materials locally and internationally.
  iii. Mapping and quantifying biomaterial resources that are available in the country.
  iv. Creating the various value chains from available biomaterials.
  v. Harnessing and adapting indigenous knowledge for sourcing earth-based raw materials and biomaterials.
  vi. Creating a database of new and emerging materials.
  vii. Identifying and promoting the adoption of new and emerging technologies for raw materials, new product development and materials processing technologies for national industrial growth.
  viii. Building institutional capacity and capabilities in earth based raw materials, biomaterials, new and emerging materials and technologies such as Advanced Manufacturing Technologies (AMT).
  ix. Promoting effective linkages and collaborations among institutions, Agencies and relevant stakeholders in earth-based raw materials, biomaterials, new and emerging technologies.
  x. Strengthening the development and proliferation of technologies and innovations for sustainable utilization of earth-based raw materials, biomaterials, new and emerging materials and new products.
- **Ferrous, Non-Ferrous and Chemical Technologies Research**
  i. Encouraging R&D in the exploration, exploitation and utilization of ferrous, nonferrous, and petroleum resources.
  ii. Building capacity and developing indigenous capability in iron and steel, petrochemical and engineering plastics development.
  iii. Promoting intense R&D activities to develop internationally competitive textiles and leather industries
- **Wood Resources**
  i. Promoting R&D in the cultivation, exploitation and application of wood resources, with value addition, to pulp, paper and timber industries.
  ii. Promoting the application of STI to create new products to provide support for Nigerian pulp, paper and timber.
  iii. Generating environmentally sustainable forest management practices, increasing capacity of processing and value adding facilities.
  iv. Facilitating emerging wood resources technology related to biofuels, biochemical, bio composites, nanocellulose, building and construction industry (timber and plywood products in innovative zero energy houses, wood plastic composites.).
  v. Building capacity through education, research and know-how technology training.

vi. Ensuring utilization of Nigerian grown timber in construction of highly efficient structural systems.

3.3.7. *Mathematics, Computational and Communication Systems*

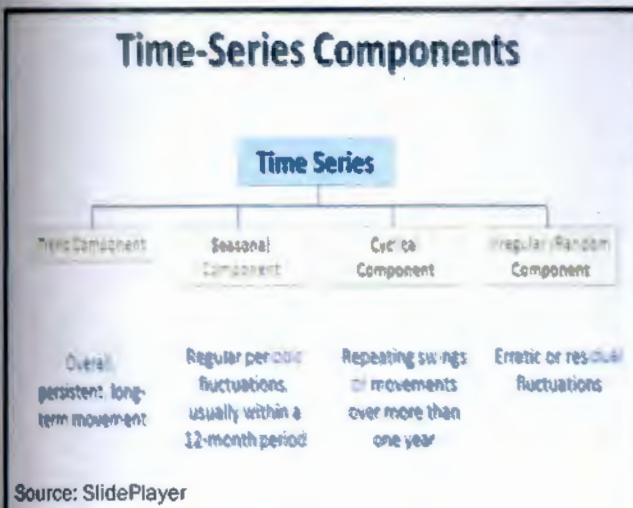
It is really a **"computational world"** as quantitative analyses aided by computers, have helped in moving countries, even those with limited natural resources, up in the ranking of global health and stealth. Advances in applications of mathematics and computing systems are essential to attainment of Nigeria's economic development targets. Many critical fields of mathematics, including time series analyses, Monte-Carlo methods, kriging, similitude, pattern recognition analyses, transport modellings, network analyses, and population dynamics are studied in textbooks without extension and application to societal challenges in Nigeria. Examples of these mathematical concepts and methods are illustrated in Figures 51-61.

Even with the desired improvement in computing infrastructure in Nigeria which implies hardware installation, the analytical component (software and computing knowledge) is its necessary complement. Many workshops exemplified by NOTAP (109), have been held to address software licensing and application issues in Nigeria. Being that the National policy on STI does not specifically address the utility of mathematical advances and applications to Nigeria's governance and industrialization thrusts, critical objectives are added herein, in that regard. Concerning research on mainstream ICT, it has been very insignificant considering the growth of the industry in Nigeria. The industry has widespread utility as illustrated in Figures 62-67.

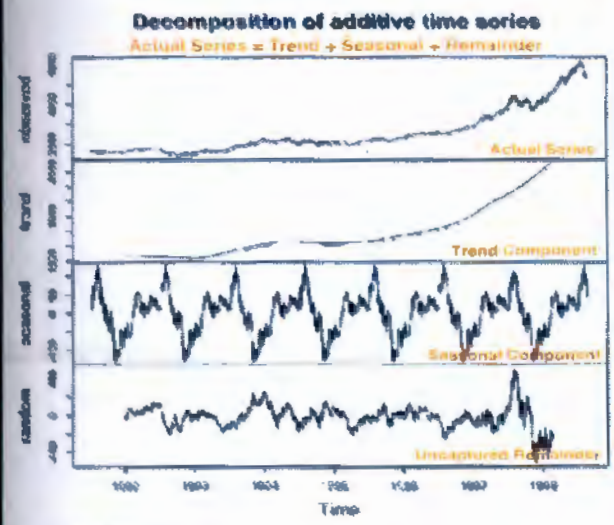
- **Mathematical Advances and Applications**
  - i. Devise measures for popularization of mathematics among the general population of Nigerians with increased emphasis on children.
  - ii. Implement adult education tutorials in urban and rural areas with basic mathematical concepts as a significant content in STEM
  - iii. Strengthen research on basic mathematics as well as applied mathematics with more extensive applications to both policy and technological challenges of Nigeria
- **Information and Communications Technology (ICT)**
  - i. Encouraging capacity building in ICT in Nigeria.
  - ii. Encouraging and supporting collaborative R&D activities among industry, higher educational institutions as well as private and public research institutions for software and hardware development.
  - iii. Developing indigenous capabilities for the local manufacture of ICT hardware, software and other accessories through technological substitution and transfer.
  - iv. Encouraging knowledge in ICT as a critical component of STI in Nigeria
  - v. Creating ICT databank in support of STI.
  - vi. Encouraging the incorporation of ICT knowledge in all sectors in Nigeria.
  - vii. Supporting ICT multidisciplinary training modules as fundamental prerequisite to prepare, drive and enhance all sectors of Nigeria's development.
  - viii. Establishing Science Parks with ICT Backbone and Software development.
  - ix. Developing special conversion programs to transform existing Engineers to ICT Specialists.
  - x. Facilitating National ICT Innovation Competition at all levels of education.
  - xi. Encouraging Industry-University-Government Networking on STI Initiatives.

3.3.8. *Space and Geospatial Systems*

This is one sector of knowledge that separates developed countries from underdeveloped and developing countries. Advances in space and geospatial systems and their applications enable countries to take stock of their resources on a spatio-temporal basis, play what-if games; and optimize their physical development targets in terms of areas and processes.

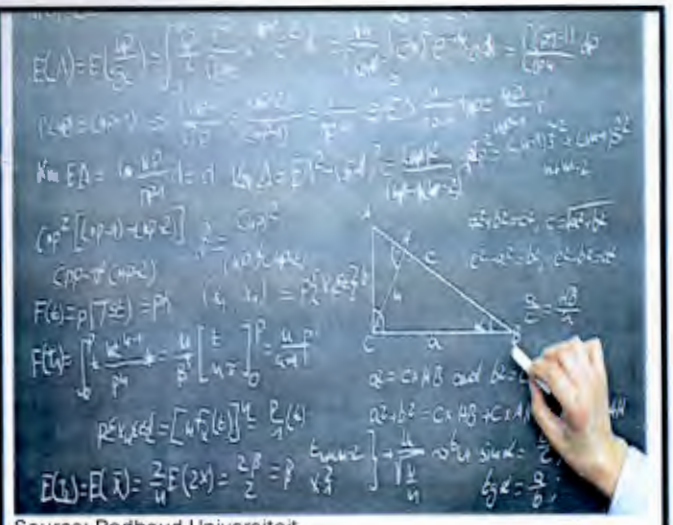


Source: SlidePlayer



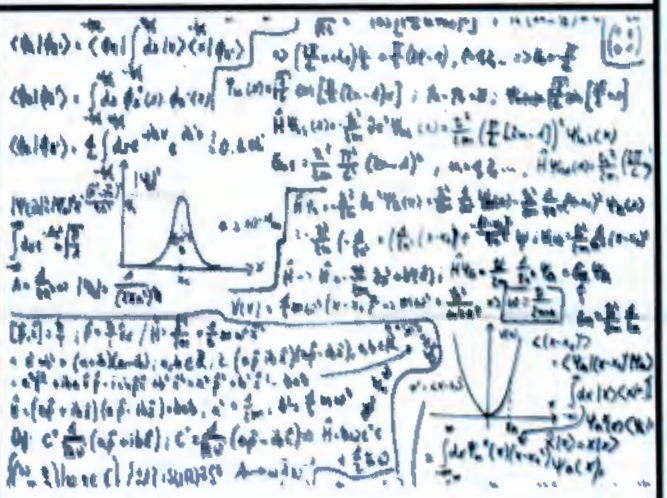
Source: R Statistics.Net

FIGURE 51: DEVELOPMENT OF TIME SERIES MODELS FOR APPLICATIONS TO REPETITIVE EVENTS IN NIGERIA



Source: Radboud Universiteit

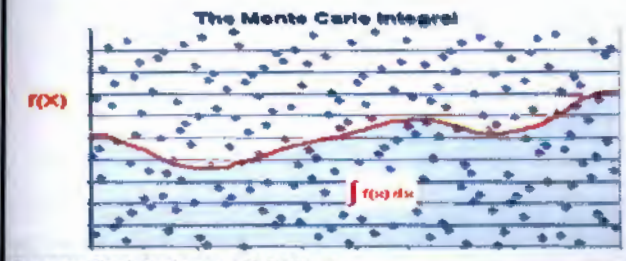
FIGURE 52: MATHEMATICAL APPLICATIONS TO SPACE EXPLORATION



Source: LinkedIn

FIGURE 53: MATHEMATICAL APPLICATIONS IN QUANTUM MECHANICS

Source: Vertex42



Source: Real Options in Petroleum

FIGURE 54: DEVELOPMENT OF MONTE CARLO METHODS TO DESCRIBE MULTIFACTOR PROBLEMS

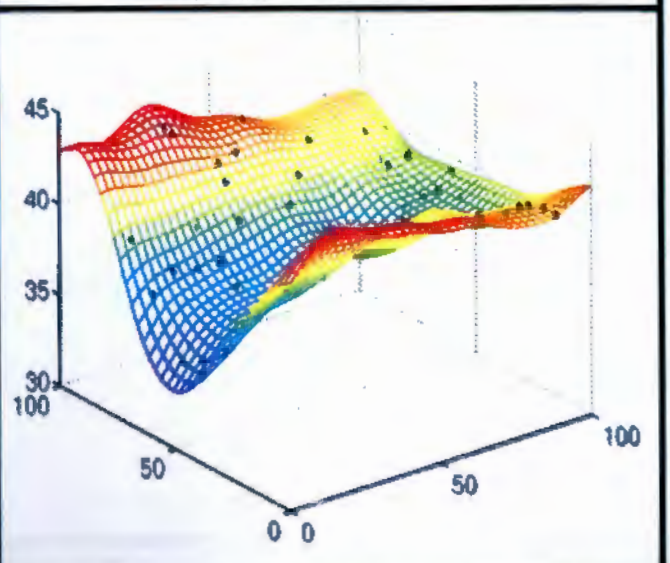


FIGURE 55: DEVELOPMENT OF MATHEMATICAL MODELS (EG, KRIGING) TO SUPPORT SOFTWARE-BASED SPATIAL MODELS

The lim-inf

$$\liminf_{h \to 0} E_1^h[s_h, \mathbf{u}_h]$$

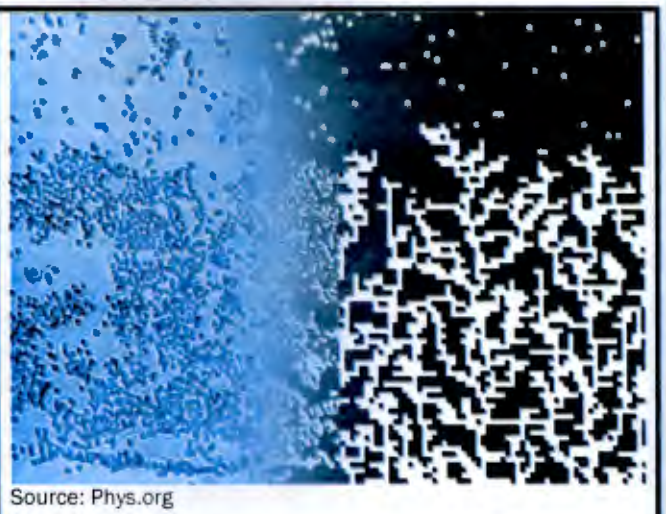
$$\geq \int_\Omega (\kappa - 1)|\nabla|\tilde{\mathbf{u}}|^2 + |\nabla\tilde{\mathbf{u}}|^2 dx$$

...using $\tilde{\mathbf{u}} = |s|\mathbf{n}$...

$$= \int_\Omega \kappa|\nabla s|^2 + s^2|\nabla \mathbf{n}|^2 dx$$

Source: Mathematical Modeling and Simulation of Nematic Liquid Crystals (YouTube)

FIGURE 56: MATHEMATICAL SIMULATION OF PROCESSES

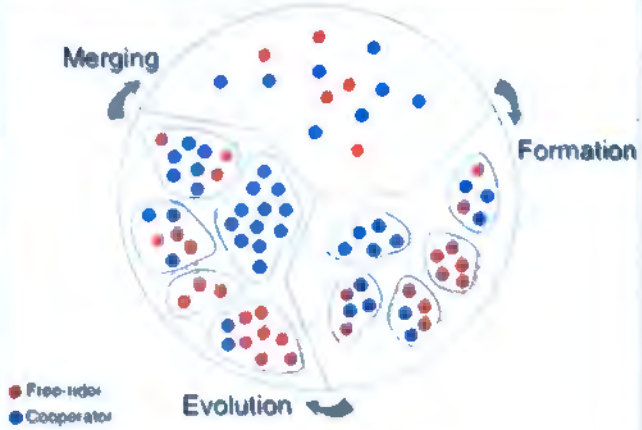


Source: Phys.org

FIGURE 57: ADVANCED PATTERN RECOGNITION IN GEOSPATIAL MODELLING

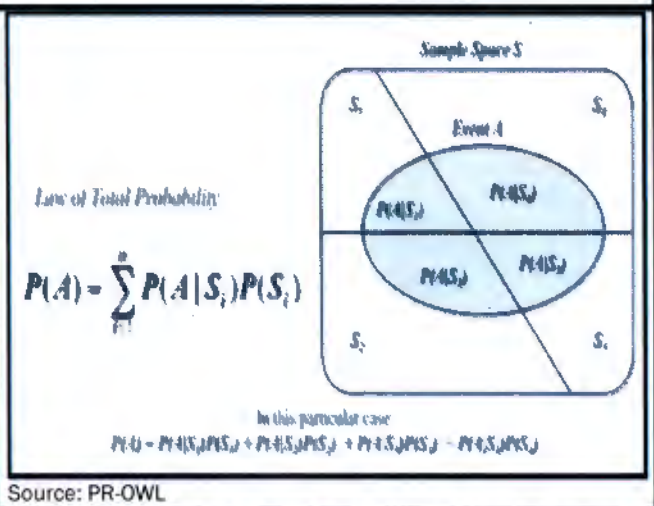
Source: SIMmersion

FIGURE 58: MATHEMATICAL SIMULATION OF OBJECTS AND PROCESSES



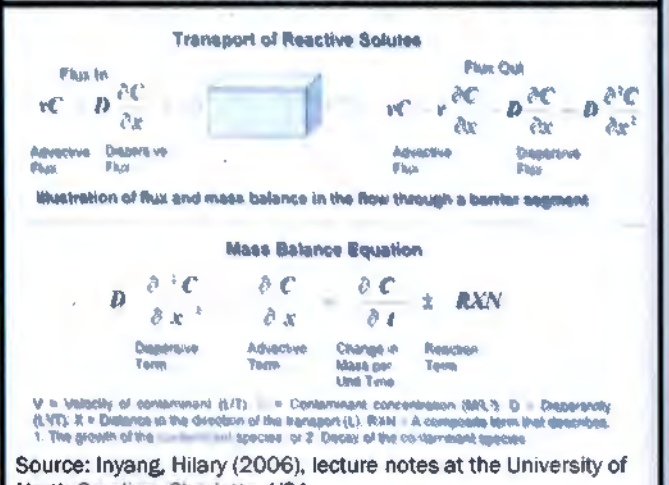
Source: www.theorie.physik.uni-muenchen.de

FIGURE 59: POPULATION DYNAMICS FOR APPLICATIONS IN ECOLOGY, HUMAN MIGRATION, FACILITIES PLANNING AND DELIVERY OF SOCIAL SERVICES



Source: PR-OWL

FIGURE 60: APPLICATION OF PROBABILITY THEORY TO PREDICTIONS IN SUCH SECTORS AS INDUSTRIAL MANUFACTURING, AGRICULTURAL PRODUCTIVITY, MINERAL PROSPECTING, HAZARDS ZONATION AND MARKET FORECASTING



Source: Inyang, Hilary (2006), lecture notes at the University of North Carolina, Charlotte, USA

FIGURE 61: FORMULATION AND APPLICATION OF CONVECTION-DISPERSION MODELS TO MATERIAL TRANSPORT AND BALANCE ANALYSES

Source: BLOMINVEST Blog

FIGURE 62: UTILITIES OF ICT FOR RESEARCH AND APPLICATION TO VARIOUS SOCIO-ECONOMIC SECTORS

Source: LSE Blogs

FIGURE 63: ELECTRONIC DEVICES FOR HUMAN-MACHINE INTERFACE

Source: The Guardian Nigeria

FIGURE 64: CLOUD COMPUTING TO SUPPORT SOCIETAL OPERATIONS

Source: Bluestone - WordPress.com

FIGURE 65: ADVANCES IN NETWORK SYSTEMS NECESSARY FOR SOCIAL INTERACTIONS AND CIVIL/ INDUSTRIAL OPERATIONS

Source: Conceptdraw.com

FIGURE 66: ADVANCES IN TELECOMMUNICATION SYSTEMS TO PROMOTE SPACE BRIDGING

Source: Abis

FIGURE 67 : ENGINEERING OF IMPROVED TELECOM MASTS FOR COMMUNICATION

There is the space travel/satellite launching aspect, as well as the analytical capacity component, both of which need to be strengthened through a well-configured and funded research programme in Nigeria. Nigeria's national STI Policy which has the following objectives on space research and investments, is the basis for selection of the NSTIR 2030 projects listed in Table 10. The STI objectives are stated below, and some of the utilities of advances in this area of knowledge are illustrated in Figures 68-70.

i. Developing adequate capacity in space technological infrastructure and research for socio-economic development.

ii. Deploying space technology infrastructure in national development.

iii. Enhancing indigenous capabilities in space research and satellite technologies.

iv. Developing space research as a critical component of national security.

v. Space Science and Technology is diverse, there is need to develop multi-disciplinary research irrelevant fields and coordinate activities in areas such as:
   - Basic Space Science and Astronomy
   - Remote Sensing
   - Satellite Technology Development
   - Geodesy and Geodynamics
   - Space Transport and Propulsion
   - Space Science and Technological Education
   - Atmospheric research

vi. Creating meaningful Nigerian Space Science and Technology programme that should enhance technological advancement such as:
   - Exploring national (Nigerian universities and other research institutions) and international cooperation in space science, technology and application.
   - Creating a conducive environment that can attract Nigerian scientists who are home and abroad.
   - Creating enabling environment to enhance the development of space science and technology infrastructure in national institutions.

3.3.9. *Artificial Intelligence and Robotics*

As a rapidly developing country with many socio-economic challenges, security and occupational exposures will become very challenging. Certain tasks in hazardous environments cannot be safely performed by humans. Examples of such tasks are bomb detonation, inspection and excavation of highly toxic materials, rescue of people from burning environments, and certain military operations. In such circumstances, it is often found necessary to deploy robots. Robots are machines that substitute for humans in the performance of certain functions. Their design, construction and operation require research and entreprise that draw expertise from a variety of technical fields, including mechanical engineering, electrical/electronic engineering, material science, photonics and signal processing. With Nigeria's industrialization targets, advances in home-grown robotics and ancillary fields such as artificial intelligence are indispensable. NSTIR 2030 covers research on robotics and artificial intelligence, the range of applications of which are illustrated in Figures 71-75.

3.3.10. *Science Communication and Technology Diffusion*

Many hard scientists and engineers often find it difficult to recognize science communication as a bona fide field that is worthy of research. Actually, it is a critical field for the translation of research results from the bench or mind to the general society or even, their prospective, commercial users. Through research that should cover cultural factors, language, socio-economic circumstances and incentives, more effective methods for the dissemination of various categories of science and technology information can be designed for specific groups and implemented. This is necessary not only for attraction of public support for sponsorship of STI projects, and acceptance of locally produced products, but for the general transformation of the Nigerian society to one that deeply values innovation. Examples of the common methods of science communication are illustrated in Figures 76-83. One of the innovative

TABLE 10: FMST's THEMATIC RESEARCH AREAS AND PLANNED TOPICS AS PART OF NSTIR 2030 WITH INDICATIONS OF RELEVANCE TO NIGERIA'S SCIENCE, TECHNOLOGY AND INNOVATION (STI) POLICY OF 2012

	FMST THEMATIC RESEARCH AREAS AND SUITES OF RESEARCH ISSUES	KEY FMST CENTER (in bold) WITH PROSPECTIVE COLLABORATORS	IMPLEMENTATION SCHEDULE													
			SHORT TERM				MEDIUM TERM					LONG TERM				
			17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.0	**BIOTECHNOLOGY INCLUDING PHARMACOLOGY**															
1.1	Database compilation on natural products and their locations in Nigeria	**NABDA, FIIRO, RMRDC**, FRIN, NIHORT, NACGRAB, NRCRI, NNMDA	X	X	X	X			X	X	X			X	X	X
1.2	Development of national biosafety and bioethics guidelines	**NABDA,** NITR, NAFDAC, NACGRAB, IITA, NBA		X	X	X										
1.3	Development of biological diagnostics and forensic tools	**NABDA, FIIRO, SHESTCO**, NRCRI, NSPRI, IART, IITA, IAR		X	X	X		X	X	X			X	X	X	
1.4	Development of post-harvest crop preservation methods to support Nigerian Agriculture	**NABDA, FIIRO, SHESTCO**, NRCRI, NSPRI, IART, IITA, IAR		X	X											
1.5	Improvement of crop breeding technologies	**NABDA,** NRCRI, NACGRAB, IART, IAR	X	X	X			X	X	X			X	X	X	
1.6	Development of tissue culture and aquaculture techniques to support agricultural expansion	**NABDA, SHESTCO**, CRIN, FRIN, NACGRAB, NIHORT, NRCRI, NIGOR, IITA		X	X	X	X	X	X	X	X					
1.7	Genetic barcoding of various plants and animals in Nigeria	**NABDA, SHESTCO**, FRIN, IART, IITA, NACGRAB NVRI		X	X	X	X	X	X							
1.8	Expansion of DNA finger-printing across Nigeria	NABDA, SHESTCO, ILRI, IITA, NACGRAB	X	X	X											
1.9	Micro-propagation of plantlets trees (Neem, Eucalyptus, Acacia, etc.) for desertification control	**NABDA,** NIHORT, NACGRAB, NIPRD, NIHORT, IITA, IART, IAR	X	X	X											
2.0	**HEALTH AND NUTRITION**															
2.1	Development of vaccines for diseases and ailments that are common in Nigeria	**NNMDA,** NIPRD, NVRI, NIMR		X	X	X	X	X	X	X	X					
2.2	Comprehensive characterization of the distribution of diabetes risk factors in Nigeria	**NNMDA,** NIMR, NCDC		X	X				X	X			X	X		

	FMST THEMATIC RESEARCH AREAS AND SUITES OF RESEARCH ISSUES	KEY FMST CENTER (in bold) WITH PROSPECTIVE COLLABORATORS	IMPLEMENTATION SCHEDULE													
			SHORT TERM				MEDIUM TERM					LONG TERM				
			17	18	19	20	21	22	23	24	25	26	27	28	29	30
2.3	Development of stem cell therapy for sickle cell anemia, Alzheimer, disease and Parkinson's disease	**NNMDA, NABDA,** NIMR, NIPRD					X	X	X	X	X					
2.4	Continuous identification, collection and assessment of farmers-preferred existing cultivars for improvement	**NABDA, SHESTCO,** NIFOR, NRCRI, NIHORT, IITA, IART, CRIN, IAR, NIFST		X	X	X	X	X	X	X	X	X	X	X	X	X
2.5	Development of various food products from local (Nigerian) crops.	**FIIRO, NABDA, RMRDC,** IITA, NRCRI, NSPRI, IAR, NIFST		X	X	X	X	X	X	X	X	X	X	X	X	X
2.6	Assessment of genetic relatedness and variability in accessions of crops and animals using AFLP markers	**NABDA, SHESTCO, NNMDA,** NACGRAB, IITA, IART, NRCRI, ACRI			X	X	X	X	X							
2.7	Cross-breeding of tilapia with local species of fish for improvement of size and other characteristics	**NABDA, SHESTCO, FIIRO,** NIFFR, NIOMR		X	X	X										
2.8	Optimization of cattle ranching in an environment of pests and other stressors	**NITR, NABDA, NILEST** NVRI, ILRI, IART, NAPRI		X	X	X										
2.9	Development of innovative techniques for management of livestock/poultry	**NITR, SHESTCO, NARICT,** NVRI, ILRI, IART, NAPRI			X	X										
2.10	Configuration and application of techniques for eradication of pests, including tse-tse fly, locusts and mosquitoes	**NARICT, SHESTCO, NITR,** ILRI, LCRI, NAPRI, NCDC,	X	X												
2.11	Comprehensive compositional analyses and cataloging of traditional/medicinal materials and their applications	**RMRDC, NNMDA, FIIRO,** IITA, NIHORT, NIPRD NIMR			X	X	X	X	X	X	X					
2.12	Performance of advanced research on stem cells and extension to bone marrow transplantation	**NNMDA, SHESTCO, NABDA,** NIPRD, NACGRAB, IMRAT					X	X	X	X	X	X	X	X	X	X
2.13	Expansion of observational studies of herbal therapies for tropical diseases,	**NNMDA,** NIMR, NIPRD, IHV-N, NCDC, CMRAP-UNIPORT, IMRAT		X	X	X										