MINISTRY OF ENVIRONMENT, SCIENCE, TECHNOLOGY AND INNOVATION

NATIONAL SCIENCE, TECHNOLOGY AND INNOVATION POLICY (2017 – 2020)

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FOREWORD

Ghana's attainment of middle-income status with per capita GDP in excess of $1,000 currently is very laudable. It is a long way from the $400 per capita of the 1990s. More importantly, the achievement sets the tone for the ambitious goal of attaining a per capita GDP of $3,000 as announced by the Government of Ghana. However, such national ambitions can only be attained on the wheels of a solid base of Science, Technology and Innovation (STI). This is the resounding lesson from the advancement of the industrialized and newly industrialized countries such as Korea, China and India.

Soon after independence in 1957, Ghana realized the importance of creating a national capacity for STI. A number of scientific institutions were built to address the challenge of a young state emerging from a colonial era and establishing its membership in the Commonwealth of Nations. The Ghana Academy of Arts and Sciences (GAAS), Council for Scientific and Industrial Research (CSIR), the Ghana Atomic Energy Commission (GAEC) and the Kwame Nkrumah University of Science and Technology (KNUST) were key institutions set up to address the crucial challenge of forging a scientific and technological base for the country's socio-economic development programmes.

Today there is an even more crucial role for STI in national development. The technological advancement the world has experienced in recent years would have been unimaginable two or three decades ago. The revolutionary effect of new technologies particularly information and communication technology (ICT), biotechnology and nanotechnology, has transformed human activities and inter-state relations in several dimensions. In agriculture, industry, education, health, commerce, finance and other sectors of the economy, the new technologies have enhanced production, processing and marketing both quantitatively and qualitatively. With regards to the internet, the scope of socio-economic realities has

expanded into virtual space. The challenge of building a national scientific and technological capacity has become more urgent and intensive.

Whereas previously the talk was mainly about "science and technology", now it is about "science, technology and innovation" and their effective application in the national economy and the wider society. There is still the fundamental problem of catching up technologically with the more advanced countries, but nowadays the emphasis is more on the essential driver and sustainer of socio-economic transformation in the world – innovation. Innovation ensures the use of knowledge to bring about scientific and technological applications which are new in the context of usage even though they may not be new in other parts of the world. In every sector of the national economy, there are specific problems to which innovation could provide good solutions. It is thus a pivot of economic growth and must be at the centre of Ghana's ability to attain its national economic vision.

The National Science, Technology and Innovation Policy therefore aims in broad terms, to provide a framework for stimulating innovation in the economy and the society. The Ministry of Environment, Science, Technology and Innovation (MESTI) has the mandate to promote science and technology application in the country and to create the conditions and enabling environment for innovations to occur. In line with this mandate, MESTI presents this policy document as the fundamental basis of its endeavours.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

At the dawn of her independence in 1957, Ghana nursed a dream of rapid social and economic development on the back of Science, Technology and Innovation (STI). In spite of the post-independence push that created much of the current scientific and technological capacity, there has not been much progress in making Science, Technology and Innovation (STI) the main drivers of socio-economic activities. The vision which fueled the passion for science-led development considerably waned after the fall of the first nationalist government of Dr. Kwame Nkrumah in 1966. Also lacking has been a definitive and prescriptive National STI policy that spells out the vision, goals, objectives and priorities for investment in STI. Such a policy would have committed government, public and private sector organizations, including the scientific institutions to specific targets for production, processing, research and development (R&D) and innovation.

On the specific issue of STI policy formulation in Ghana, one such policy document was adopted by Cabinet in 2000. In 2001 a working document on the management and administration of science and technology policy was prepared. However, both documents did not advance to the implementation stage. Another significant move was made in 2004 to showcase science and technology as a major tool for development. It involved a high profile conference, dubbed the **First National Forum on Research, Science and Technology (March 2004)**, and was graced by the President himself and his ministers. The conference promised much in enthusiasm for science and technology and closed with a communiqué which spelt out specific activities for implementation. However, Science and Technology policy implementation suffered yet another setback when the sector Ministry of Environment and Science was dissolved in 2006, with the Science portfolio being absorbed by the Ministry of Education which then became known as the Ministry of Education, Science and Sports.

It is in the above context that the current *National Science, Technology and Innovation Policy* has been crafted for adoption. It has benefited from earlier documents, having been reviewed by a cross section of the science and technology community including scientists and policy makers. Unlike previous documents, the concept of *innovation* is strongly embedded in the new framework of actions, policies and programmes to apply science and technology towards social and economic objectives. Innovation implies the application of *knowledge* to bring about scientific and technological improvements to socio-economic activities where such applications are new in the context of usage even if they are not in other contexts. It is critical that scientific knowledge in whatever form be translated into direct application to benefit economies and societies in one way or other. This is the leg on which the STI policy stands.

Vision, Goals, Objectives

In STI terms, Ghana's vision is to develop to become a high–income country which fully applies and integrates STI into national development strategies. This positions the country to harness the nation's total science and technology capacity to achieve national objectives for poverty reduction, competitiveness of enterprises, sustainable environmental management and industrial growth. Specific objectives are to:

a) facilitate mastering of scientific and technological capabilities;
b) provide a framework for inter-institutional collaborations in developing STI programmes in all sectors of the economy to meet the basic needs of the society;
c) create the conditions for the improvement of scientific and technological infrastructure for research and development and innovation;

d) ensure that STI supports Ghana's trade and export drive for greater competitiveness;
e) promote a science, technology and innovation culture in the wider society.

The policy will be driven on the principles of relevance, realism, cost-effectiveness, synergy and partnership, especially with the private sector.

Sector-Specific Policy Strategies

The principal thrust of the National Science, Technology and Innovation Policy is to ensure that science and technology drive all sectors of the economy. In order to achieve these objectives, sectoral policies, programmes and strategies would be implemented on the basis of the overall National Science, Technology and Innovation Policy. Sectoral policies in Agriculture, Health, Education, Environment, Energy, Trade, Industry, Natural Resources, Human Settlements and Communications shall be driven by sector-specific Science, Technology and Innovation programmes and activities. In this regard, this policy document highlights some specific activities and programmes of individual sectors.

Management of Science, Technology and Innovation Policy

The Ministry of Environment, Science, Technology and Innovation (MESTI) will have the primary responsibility for the Science, Technology, and Innovation (STI) policy and will manage and implement Government's STI policies. This mandate will be executed through the organizations operating under its auspices and where necessary through other relevant organizations. The cabinet minister as the political head of the Ministry would provide the needed leadership to link with other ministries and organizations for STI application and development in the country. The STI Directorate of the

Ministry would be its nerve centre. This is the Directorate responsible for policy formulation and the development of appropriate STI strategies and programmes.

An apex STI body – the Presidential Advisory Council for Science, Technology and Innovation - shall be established to ensure strong advocacy for STI in the country, to provide advice to the President, and to ensure coordination and harmonization of the nation's STI policy and programs. This body would serve as a Think Tank with representation from the Ghana Academy of Arts and Science (GAAS), the Council for Scientific and Industrial Research (CSIR), Ghana Atomic Energy Commission (GAEC), universities, professional science and technology-based associations, among others, to provide the STI oversight and advice for policy formulation and implementation.

Financing STI

Government would take steps to address the inadequacy of STI funding which has handicapped the country's progress in the past, and would accordingly increase public expenditure to achieve the ends of the current renewed commitment to use science and technology as major drivers of sustainable economic growth. Government would make appropriate arrangements for financing the science and technology development and delivery system. To this end, Government will, among other things:

a) Review all existing funding lines supporting development in science and technology and industry with the aim of streamlining them to achieve higher efficiencies in their operation;

b) establish a National Science, Technology and Technology Fund to incorporate support for innovation in its sphere of operations;

c) work to ensure the allocation of a minimum of 1% of the Ghana's Gross Domestic Product (GDP) to support the science and technology sector;
d) institute an attractive tax incentive scheme to benefit contributors to the said STI Fund or other R&D activities.

1. CHAPTER: INTRODUCTION

Ghana, as a typical developing country, grapples with many development challenges. In agriculture, industry, health, environment and all other sectors, there are challenges militating against the quest to improve the society and the quality of life for all Ghanaians. However, attaining the development vision is not impossible. The first and foremost step is to harness Science, Technology and Innovation (STI) to address the development challenges. To enable a constructive and structured harnessing of STI, the National Science, Technology and Innovation policy has been formulated taking into account the social and economic context and the imperatives of Ghana's development. The policy is for the period 2017 to 2020.

1.1 Background

Science and Technology (S&T) are perceived the world over as major tools for rapid social and economic development. The most industrialized economies of the world achieved their status by applying Science, Technology and Innovation (STI) to their productive processes. . China, South Korea, India, Malaysia, Singapore, and a few other countries followed in the footsteps of the major industrialized countries by successfully applying STI to transform their economies. For example, the very rapid economic transformation that has taken place in the Republic of Korea, in contrast to Ghana, is generally attributed to Korea's greater success in acquiring and applying scientific and technological knowledge in her national development. Yet at the dawn of independence in 1957, Ghana also nursed a similar dream of rapid social and economic development based on S & T. Dr. Kwame Nkrumah at the last meeting of the old legislative assembly on the 5th of March, 1957 declared:

"Our whole educational system must be geared to producing a scientifically-technically minded people. Because of the limitations placed on us, we have to produce, of necessity, a higher standard of

technical education than is necessary in many of the most advanced countries of the Western world … I believe that one of the most important services which Ghana can perform for Africa is to devise a system of education based at its university level on concrete studies of the problems of the tropical world. The University will be the coordinating body for education research, and we hope that it will eventually be associated with Research Institutes dealing with agriculture, biology, and the physical and chemical sciences which we hope to establish …" (McWilliam & Kwamena-Poh, 1975:94)[1].

This vision drove the impressive array of S & T institutions that sprang up within a few years after independence. Among these were National Research Council (now the Council for Scientific and Industrial Research) established in 1958 to operate Research and Development (R&D) institutes, and the Ghana Academy of Learning, a learned society, established in 1959 which became the Ghana Academy of Sciences in 1961.

President Kwame Nkrumah at the Fourth Anniversary of the Ghana Academy of Sciences again stressed the critical role science and technology play in socio-economic development as follows:

"We believe not only in pure research as a legitimate endeavor, but we also attach great importance to applied research. Modern science has taught us enough, and has already given us enough, to be able to tackle our agricultural, industrial and economic problems. ….Only the mastery and unremitting application of science and technology can guarantee human welfare and human happiness" (Obeng, 1997; p. 309[2])

In 1966, following the overthrow of Dr. Nkrumah, changes were made to the Academy which was re-designated the Ghana Academy of Arts and Sciences (GAAS). The research institutes were placed under a new

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[1] MacWilliam, H.O.A. and Kwamena Poh, M.A. (1975) *The Development of Education in Ghana*, Prentice Hall Press, London.
[2] Obeng, S. (1997) "The Academy of Sciences Dinner", *Selected Speeches of Kwame Nkrumah Vol. 2*, Centenary Edition, Afram Publications (Ghana) Ltd., Accra, pp. 307 – 321.

body named the Council for Scientific and Industrial Research (CSIR) which in its present form was re-established in 1996 with thirteen (13) Research Institutes. Over the years more scientific and technological institutions were established. These include the Ghana Atomic Energy Commission, Environmental Protection Agency, Noguchi Memorial Institute for Medical Research and the Standards Authority.

Alongside, and central to the functioning of, the research establishments and government agencies, are the universities, which perform the important task of training the high level human resource to run and manage them. The University of Ghana began in 1948, as the University College of the Gold Coast. The Kwame Nkrumah University of Science and Technology began as the Kumasi College of Science and Technology in 1951. The University of Cape Coast started in 1961. As of 2017, Ghana has ten public universities, and 74 private universities[3]. With these universities, eight technical universities, two polytechnics, over 500 senior high schools 23 technical institutes, and a large informal sector where most artisanal skills training take place, Ghana can be said to have a substantial education and training capacity for human resource development in STI. Inadequate staffing, laboratory and workshop facilities have however limited the capacity of these institutions to produce the number and quality of high level scientists, engineers and technologists, technicians and artisans required to support the system.

With the re-designation of the Ministry of Environment, Science, Technology and Innovation in the Fourth Republic, which began as the Ministry of Industry, Science and Technology, the potential for effective promotion, management, coordination and harmonization of STI policies and institutions have finally been placed in the mainstream of the government machinery.

However, the premium placed on science and technology as the main drivers of development, by policy makers and managers of the

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[3] National Accreditation Board (as of 4th May 2017) *http://www.nab.gov.gh/*

nation's resources, has not been high. . The proportion of the nation's budget allocated to science, technology and innovation has been low. It has fluctuated between 0.3% and 0.5% of the Gross Domestic Product (GDP). This is well below the target of 1% prescribed at the Summit of African Heads of State of the Organization of African Unity (OAU) in 1980 under the Lagos Plan of Action and adopted by the African Union (AU) as a critical means of realizing the goals and objectives of the New Partnership for Africa's Development (NEPAD). In contrast, South East Asian countries such as Korea, Singapore and Taiwan have spent as much as 2 per cent of GDP on S & T. Further, the continued inability of industry to absorb young graduates of science and engineering means that succeeding younger high-school generations are attracted more to medicine and related disciplines rather than the pure and engineering sciences. The situation is even worse with respect to the middle level professionals and technicians who are needed to keep industries and other technological systems functioning.

Thus, in spite of the post-independence push to create STI capability, Ghana has not made as much progress as countries in South East Asia whose levels of development were not higher than Ghana's at the dawn of her independence. Ghana has not had a definitive and prescriptive National Science, Technology and Innovation (STI) policy document to spell out policy directions for various sectors of the economy and associated prioritized investments. Though a National Science and Technology Policy which provided a broad framework for defining goals and objectives for S & T for socio-economic development was approved by Cabinet in 2000, it did not advance beyond this stage into full implementation. In 2001 a working document on the management of STIpolicy was prepared, and the convening of the First National Forum on Research, Science and Technology in 2005, which saw the high-level participation of the President and his ministers, brought the science community a lot of hope. Even more so when the Forum closed with a communiqué spelling out specific activities and programmes to advance science and

technology for development. Unfortunately, previous Science and Technology policy implementation suffered another major setback when the then Ministry of Environment and Science was dissolved in 2006. The science portfolio was absorbed by the Ministry of Education which became the Ministry of Education, Science and Sports.

However, advances in S&T with wide applications, such as innovations in Information and Communications Technologies (ICT) and Internet applications, as well as emerging trends in biotechnology and nanotechnology, made it imperative for Ghana to review its S&T policy to re-formulate a more comprehensive and vigorous approach to building a more modern scientific and technological capacity.

Meanwhile, competitive pressures on the national economy are enormous. The global trade environment which is dominated by rapidly emerging technologies and processes is gradually becoming threatening to local African enterprises. Climate change and its consequences in terms of food crises and threats to human welfare are affecting Ghana just as it is doing to the entire world ecosystem. However, the opening up of trade opportunities in the global markets in general and the mounting requirements of the World Trade Organization Treaty on Technical Barriers to Trade (Uruguay Rounds of Talks) pose opportunities and risks to the developing economy of the country. Local enterprises can still be competitive in the global trade environment with enhanced innovation and scientific content in their operations in all areas. In this regard, Ghana as a matter of urgency needs to make urgent policy decisions to harness STI in the development process.

It is in the context of the above that this National Science, Technology and Innovation Policy framework has been crafted for adoption. It has benefited from earlier documents and was reviewed by a cross section of the science and technology community including social scientists. The policy goals, objectives, approaches and mechanisms to achieve this, have taken account of investment in infrastructure, education

and training, research and development and science acculturation, among other things.

Unlike previous documents the concept of *innovation* is strongly welded into the new framework of actions, policies and programmes to apply science and technology to achieve social and economic objectives. Innovation is here defined as the use of *knowledge* to bring about scientific and technological applications to enhance socio-economic activities where such applications are new in the context of usage even though they may not be new outside of the context. It is critical that today, scientific knowledge in whatever form must be translated into direct application benefiting the economy and society in one form or the other.

The emphasis on innovation comes from the realization that technologies bring about desired changes only when they are fully integrated into local systems and practices. The sound application of scientific and technological knowledge to effect positive changes has to take into consideration cultural norms and the total world view of the people who are the users of the new technologies. Innovation therefore connotes these complex interactions among science, technology and the society. The policy thus provides a broad framework for addressing the multi-dimensional demands of STI development and usage.

1.2 Existing Institutional Arrangements for Science, Technology and Innovation

Over the years, there has been considerable re-structuring and re-organization of the Government Ministry responsible for STI with the aim of addressing specific developmental challenges. Now there is a strong consensus that the Ministry of Environment, Science, Technology, and Innovation (MESTI) which was re-designated as such in 2014 should be the sector ministry under the Presidency

responsible for the management and implementation of Ghana's science and technology policies. This repositions the Ministry to oversee and coordinate the activities and programmes of the Council for Scientific and Industrial Research (CSIR) with its thirteen research institutes, the Ghana Atomic Energy Commission (GAEC), the Environmental Protection Agency and Town and Country Planning Department, whose collective primary responsibilities are applied Research and Development (R&D) in Ghana.

A major role for MESTI which has so far not been executed fully is promoting its linkages to the Ministries of Education, Trade and Industry, Employment and Social Welfare, Communications and Lands and Forestry, etc. and indeed all other Ministries to ensure that the educated, trained and skilled human resource in whom the national science, technology and innovation capability resides are available in adequate numbers to achieve national objectives in economic development. An issue of concern is inadequate commitment over the years to train larger numbers of scientists, engineers and technologists to sustain the national scientific capability. Making matters worse, Ghana lost many of its trained persons through brain drain, and unlike other countries, use of experts in the Diaspora has not been factored into a national-assets utilization plan. There needs to be a national register of Ghanaian experts and other skilled persons living in foreign lands. Though their remittances have become a major income base for the economy, their intellectual contributions are even more desired and could be a source of some technology transfer.

A third area of concern for building Ghana's STI capacity is the inadequacy and failure to develop the capacity of the universities to educate and train significant numbers of scientists and technologists to the level of Ph.D. Correcting this shortcoming would strengthen the universities to conduct not only applied R&D but also effective basic research. A National Science, Technology and Innovation Policy must encourage Ghana's scientists and technologists to link up with international research centres where world class basic research is

being conducted so that Ghana is not left behind or isolated from such pursuits at the frontiers of human knowledge and understanding. The technical universities and polytechnics must be made to educate and train high-level technicians and technologists in larger numbers to provide high skilled support for national STI. This will not happen if immediate action is not taken to reverse the shift away from science and technology that is taking place in the technical universities for reasons not beyond correction.

1.3 What Constrains STI Application?

Ghana has made much investment in science and technology infrastructure and in creating a national STI system over the years. Although some significant achievements have emerged from the system, these investments have not yielded the expected improvements in economic growth. This can be attributed to a number of constraints including the following:

a. inadequate scientific expertise in the country;
b. Lack of effective advocacy for STI at the highest political and policy levels;
c. Low science and technology culture among the populace;
d. Weak structures for the management of STI;
e. Ineffective coordination of the STI system
f. Inadequate budget and resource allocation to STI;
g. Weak linkage between policy formulation and national development planning;
h. Weak mechanisms for implementation, evaluation and review of STI projects and initiatives;
i. Weak linkages between various agencies and organizations in STI;
j. Weak linkage between industry and the R&D system;
k. Over reliance on the use of foreign expertise to the neglect of the use and development of local expertise;

l. inadequate science teaching and learning in our pre-tertiary education system;

m. Poor remuneration and conditions of service for science and technology personnel of research institutions.

If these limiting constraints can be removed, STI in Ghana would advance rapidly. Many calls for these constraints to be addressed have come from annual and biennial resolutions of professional bodies which represent the science and technology communities. Advocacy for STI would be greatly strengthened if Ministers of State and the President can engage from time to time and interact with the scientists, engineers and technologists, working with them to address the above constraints.

1.4 Justification for Science, Technology and Innovation Policy

The priority themes underpinning Ghana's National Science, Technology and Innovation Policy together form the agenda for the restructured Ministry of Environment, Science and Technology. They provide ample justification for the STI policy. These are:

- Promoting competitiveness in productive sectors of the economy;
- Creating job opportunities and employment;
- Expanding industrialization;
- Enhancing the quality of life through innovation;
- Developing world-class scientific and technological human capital;
- Expanding infrastructure for R&D;
- Promoting an information society;
- Optimizing the sustainable use of the natural and environmental resources;
- Commercializing research findings.

The integration of STI applications in socio-economic development gives Ghana's development plans a better chance of succeeding.

A summary policy statement is indicated, in Box 1.

Box 1: Policy Statement on STI

The National Development Planning Commission (NDPC) stated its vision for Ghana as "a modern economy based on the development of science and technology." To achieve this vision, Ghana will need a modern, efficient framework for promoting science, technology and innovation (STI) and for managing the country's STI policies, programs, and institutions. Ghana's STI framework should reflect international best practice, lessons and experiences, which should be adapted for implementation in Ghana.

Since independence , Ghana's leaders have recognized that STI should play a central role in modernizing Ghana's economy, improving living conditions, and solving social problems. This recognition spawned several previous efforts to modernize the STI system and ensure that Ghana's research institutes and universities live up to their promise of serving as an effective instrument for Ghana's growth and development. STI has been highlighted in almost every recent Government vision and planning document, including Vision 2020, the subsequent Vision 2015, the National Science and Technology Policy of 2000, and the Growth and Poverty Reduction Strategy (GPRS II). The Ghana Poverty Reduction Strategy Paper I (1996 – 2005) also has a section on science and technology. Further, the Growth and Poverty Reduction Strategy (GPRS II, 2006-2009) also makes reference to the importance of Ghana's national development.

In 2010 , the NDPC prepared and published the Ghana Shared Growth and Development Agenda (GSGDA 2010 – 2013). This Agenda underlines science, technology, and innovation as the key

elements of Ghana's development strategy, and is seen as an affirmation of Ghana's recognition of the indispensable role of STI in national development.

Ghana's efforts to articulate the policy framework for STI application is also linked to sub-regional commitments as outlined in the ECOWAS Revised Treaty as well as the NEPAD. The ECOWAS Revised Treaty requires member states to ensure proper application of science and technology to the development of agriculture, transport and communications, industry, health and hygiene, energy, education, and manpower and the conservation of the environment. The NEPAD S&T Consolidated Plan of Action (2006-2010) sets forth a series of "collective actions to develop and use science and technology for the socio-economic transformation of the continent and its integration into the world economy." These include such STI capacity building projects and programs such as:

a. Improving infrastructure or facilities for R&D;
b. Creating institutional and policy arrangements that enable African countries to mobilize and share their scarce resources to conduct science and generate technological innovations;
c. Strengthening the continent's human skills base by increasing the number of scientists, technicians and engineers;
d. Improving the quality and intensity of regional cooperation;
e. Building a strong political and civil society constituency for science and technology in Africa;
f. Improving the quality of science, technology and innovation policies of African countries;
g. Strengthening the capacity of regional economic bodies to mainstream science and technology into their sectoral programs and projects;
h. Promoting the application of science and technology to achieve specific Millennium Development Goals (MDGs);
i. Promoting innovative ways and means of financing science and technology in Africa.

The strategic role of STI in Africa's development has been further elaborated in the Science, Technology and Innovation Strategy for Africa (STISA-2024), which the Heads of States of Africa committed to in 2014, to guide the development and application of STI in Africa within the next ten years (to 2024). The stated mission of STISA-2024 is to accelerate Africa's transition to an innovation-led, knowledge-based economy (African Union Commission, 2014)[4]. This is to be achieved by improving STI readiness in Africa in terms of infrastructure, professional and technical competence, and entrepreneurial capacity; and implementing specific policies and programmes in STI. By the adoption of STISA-2024, the African leaders have emphasized the crucial role of STI in addressing the development challenges facing the member countries. For Ghana, the formulation of strategic policies and programmes to actualize the STISA-2024 vision is not only to conform to the expectation of the AU, but also to provide the strategic basis for sustainable development.

Indeed, Ghana must build national capacities for utilizing science, technology and innovation for facilitating growth in all aspects of social and economic life. The National Science, Technology and Innovation Policy provides the framework to create the institutions and develop the human resource base. The Policy also makes the appropriate financial arrangements to harness the available science, technology and innovation capacity for sustainable socio-economic development.

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[4] African Union Commission (2014) Science, Technology and Innovation Strategy for Africa (STISA-2024), AUC, Addis Ababa.

2. CHAPTER: VISION, GOALS, OBJECTIVES AND PRINCIPLES

In the 21st Century globalised world, and after sixty years of political independence, Ghana should not still be exporting the larger part of its gold, cocoa, diamond, bauxite and other commodities in their raw state. The country must build the industrial base to use the skills of a trained workforce to add value to these commodities before they are exported, to generate more wealth. In addition, Ghana must create the capacity to produce more and more knowledge intensive goods and services not directly dependent on natural resources. This STI policy envisions and plans for such a future where technology-enabled high-value goods and services generate high-value jobs for thousands of school leavers and university graduates, and the country itself can earn more revenue to achieve its social and economic objectives. Without such a prospect the most talented of Ghana's young people would not be motivated and attracted into careers in science, mathematics, engineering and technology. At present many of those who in the past have chosen careers in these disciplines have left and joined the diaspora in search of greener pastures, adding to the brain drain.

Ghana requires policies to build an educational system to produce skilled personnel to drive a modern economy. Such a policy would minimize the brain drain. Investments in the development of high STI capacity, collaborations with developing and advanced economies must derive from a vision with this objective. In mapping this future Ghana must seize the marketing opportunities for value-added products and services in the West African sub-region and in Sub-Saharan Africa as a whole.

2.1 Vision

The STI Policy projects a vision of Ghana transformed to **a developed country** with STI as the key driver. The policy is to build a strong STI capacity to drive the social and economic development for the **sustainable transformation** of the economy. The intention is to migrate the country from the current low science- and technology-poor practices and worldview associated with a society of tradition-bound culture, to an **STI and knowledge-based society** functioning within an economy based on high levels of productivity in all the sectors of the economy (namely agriculture, industry and services).

In sum, Ghana's STI policy seeks for the country a future where STI capability underpins sustainable production and processing of natural resource endowments while empowering the knowledge base to participate actively in the production of higher technology goods and services for local consumption and export. Essentially, sustainability, as encapsulated in the SDGs will underpin all STI activities in the interest of the environment, society and the economy.

Goal

Given the historical background of Ghana's efforts in STI application and development, the STI policy must be contextualized and fully integrated into a national development strategy which fully harnesses the nation's total science and technology capacity to achieve national objectives for wealth creation, poverty reduction, enterprise competitiveness, sustainable environmental management and industrial growth.

2.2 Objectives

The basic objectives of the Science, Technology and Innovation Policy are to:

- facilitate mastering of scientific and technological capabilities by a critical mass of the products of all institutions;
- provide the framework for inter-institutional efforts in developing STI and programmes in all sectors of the economy to provide the basic needs of the society;
- create the conditions for the improvement of scientific and technological infrastructure for research and development and innovation;
- ensure that STI supports Ghana's trade and export drive for greater competitiveness; and
- promote a science and technology culture in the society.

2.2.1 Long-term Objectives (Ten years and beyond)

In the long-term, the main objectives are to create endogenous science and technology capacities appropriate to national needs, priorities and resources, and to create a science and technology culture whereby solutions to socio-cultural and economic problems of individual Ghanaians, their communities and the nation as a whole are recognized and sought within the domain of science and technology.

In the long term, Ghana STI policies must address issues such as runaway population growth with its potential to slow social and economic growth and degrade the environment. Ghana's STI policies would also address climatic change and move away from carbon based energy utilization to the use of renewable energy.

2.2.2 Medium-Term Objectives (of between five and ten years)

In the medium term of between five and ten years, the objective is to accelerate the promotion of innovation through the development and utilization of modern scientific and technological capabilities to provide the basic needs of the citizenry and to create the conditions for Ghana's competitiveness.

In considering acquisition, mastering, development, improvement and diffusion of new technologies, a chance remains to leap-frog from the current low-technology status to more knowledge-intensive technologies. For example, the speed with which mobile telephony has outpaced the traditional land-based systems shows what new technologies can do. Second, the use of telecommunication and other distance-learning technologies in teaching and learning may have a similar effect regarding the expansion of access to education.

2.2.3 Short-Term Objectives (Up to five years)

The short term (of within five years) objective is to restructure the entire science and technology machinery, infrastructure and programmes in order to make them more responsive to national needs and priorities in all sectors of the economy. To that end, emphasis will be placed on:

- restructuring of the National Science and Technology Advisory system.
- improving basic and applied research infrastructure;
- revitalizing the teaching of science at the basic, secondary and tertiary levels of the education system;
- promoting the training of a critical mass of middle-level technical personnel to address the provision of basic needs;

- acquisition of skills in high technology areas such as ICT, biotechnology and nanotechnology and their integration into known technologies;
- promoting mastery of known technologies and their application in industry.

2.3 Guiding Principles

The effective implementation of the STI Policy will be guided by these key principles:

a. **Relevance:** Under this principle each STI initiative is subjected to critical examination to determine its relevance to the country's development;

b. **Cost-effectiveness:** This principle requires each STI initiative to be cost-justified in terms of the methods it employs to achieve the desired results;

c. **Realism:** Despite the lofty nature of Ghana's aspiration regarding reaching the frontiers of STI application and development, the need for realistic targets in the short and medium term must always be borne in mind.

d. **Synergy:** STI development and application must be holistic; and there must be a multi-disciplinary and cross-sectoral approach to problem-solving for synergy;

e. **Partnerships:** There must be conscious efforts for strategic collaboration with all local and foreign stakeholders as partners in development, especially with the private sector.

f. **Job and wealth creation:** An STI initiative or intervention should hold promise for developing capacities to create jobs and wealth.

g. **Demand-driven potential:** Investments in STI capacities are to be market or society-driven.

h. **Sustainability:** Ghana also commits to the global Sustainable Development Goals and therefore the principle of sustainability must underpin all STI activities.

3. CHAPTER: SECTOR-SPECIFIC POLICIES AND MEASURES TO APPLY STI

The principal thrust of the national science, technology and innovation policy is that advances, insights, tools and practices which derive from science and technology will be sought and applied in all ministries, departments and agencies, and in all sectors for social and economic development. In other words, STI will be the driver underlying the achievement of sectoral goals, objectives and programmes. All ministries will be expected to have STI desk offices to work in cooperation with the MESTI to ensure that sector programmes and activities are indeed driven by STI programmes.

In order to achieve these objectives, it is essential to facilitate the implementation of sectoral policies, programmes and strategies by the respective sectors on the basis of the overall National Science, Technology and Innovation Policy. Agriculture, Health, Education, Environment, Energy, Trade, Industry, Natural Resources, Human Settlements and Communications, etc., are expected to identify programmes and activities whose execution will be enhanced by the most appropriate and effective tools derived from STI and ICT.

This section of the National Science, Technology and Innovation Policy highlights some programmes and activities of selected sectors which can be driven by applications from STI. Core activities and programmes that are required in sector ministries, departments and agencies to apply science, technology and innovation will begin with knowledge and skills development as well as research and development in all sectors.

Well educated and trained high level scientists and technologists with specialist knowledge and skills will be required to provide specific services to enable all sectors discharge their vision and mission. Quality and diversity of education and training in the universities and polytechnics must meet international standards of excellence

otherwise quality service would continue to depend on expensive foreign expertise. Whereas such personnel may be required in specialized areas, Ghanaians in the diaspora must be recruited or engaged to augment local capabilities and provide leadership where necessary. The GET-Fund should provide funding to seek out Ghanaians abroad and foreign nationals to fill gaps in education and training.

Research institutes of the scientific institutions must be well staffed and equipped to provide the research and development needs of all ministries, departments and agencies, and the private sector. Their priorities must be well defined, reviewed regularly to ensure their relevance not only to the formal sector but also indigenous businesses, and the large informal sector where most Ghanaian production and processing activities are located. As the times, conditions, and circumstances change, corresponding changes in vision and mission will be made in response where necessary. New institutes may be set up if found necessary.

The programmes envisaged for agriculture, environment, health, energy, education, industry and trade ministries are highlighted below to show how some specific activities and programmes can enhance the quality of services that can be provided within the framework of mainstreamed science, technology and innovation policies.

3.1 Agriculture

Agriculture is critical to achieving food security. It provides jobs for 60per cent or more of the workforce and contributes about 20 per cent to Ghana's GDP. Agricultural productivity at every level of the chain of production, processing, packaging and marketing will be made to benefit from quality relevant research and development. It will require the knowledge and skills of an army of scientists of many specializations, engineers and technologists, and many social scientists including economists, sociologists, geographers and

statisticians, etc. The success that the Gold Coast made with the production, storage and marketing of cocoa was largely based on the research and development activities of the Cocoa Research Institute of Ghana (CRIG). Applying the lessons of CRIG to other crops would require that the *Crops Research Institute, Oil Palm Research Institute, Savanna Agricultural Research Institute* are better strengthened and focused on agricultural productivity issues. Similarly, the other research institutes of the CSIR, namely, the *Animal Research Institute*, the *Water Research Institute* and the field agricultural research stations of the University of Ghana at Nungua, Kade and Kpong must be positioned and better funded to advance their operations. Other research and development programmes which can increase agricultural productivity and in the process, increase wealth and reduce rural poverty include the following:

i. Promoting the research and application of new technologies including safe biotechnology, which holds potential for increasing productivity;

ii. Reducing pre-harvest and post-harvest losses in agricultural production in both cash and food crops;

iii. Strengthening STI capacity for livestock agriculture and the full development if its value chain especially for poultry and small ruminants;

iv. Promoting sustainable exploitation of fishery resources and the development of aquaculture

v. Promoting the development of food processing industries and enhance value addition for the local market and for exports;

vi. Strengthening the production of non-traditional export commodities to enhance the diversification of the economy;

vii. Strengthening the linkage between research and agricultural extension;

viii. Enhancing food and nutrition security by increasing the production of local staples such as maize, cassava, plantain and yam;

Promoting agricultural raw materials for agro-industry and job creation.

3.2 Health

The mission of Ghana's health system is the promotion of activities and programmes to prevent, control and treat diseases affecting the citizenry. Science, technology and appropriate innovations can facilitate the processes to achieve the goals and objectives of the health care delivery system. Preventive and public health measures to improve sanitation, hygiene and supply of good drinking water and also improved nutrition will be more vigorously pursued with increased use of science, technology, and innovation. Ghana's health burden is unduly exacerbated by ignorance and superstitious beliefs and practices of the people. Investment in dissemination of scientific information in the mass media to change the world-view of the Ghanaian people would save more lives and reduce the national cost of health care.

A major aspect of the mission of the healthcare system pertains to the education, training, attraction and retention of health professionals. From the early successes of training and education of preventive and public health technicians and technologists, Ghana's health sector advanced into establishing the premier medical school at Korle Bu using local medical specialists. These locally trained doctors have been accepted all over the world. Recent success in establishing the National Cardiothoracic Centre is evidence that local capacity can be developed internally. With the establishment of the Noguchi Memorial Institute for Medical Research, Ghana has demonstrated

that preventive and public health can co-exist with high-tech medical practice.

The above is the context within which to craft a vision and mission for quality health services driven by appropriate technologies and innovations driven by science and technology. Some programmes to implement in the health sector include:

i. Promotion of preventive and regenerative health care;
ii. Support of biomedical research in prevalent diseases in the areas of prevention, diagnosis, therapy and management;
iii. Improving access and services in the general health care delivery system;
iv. Promoting technologies in support of sanitation, environmental and occupational health;
v. Promoting research and development in the area of bio-medical engineering and instrumentation, as well as the potential of information technology application in the health delivery system;
vi. Enhancing the development of human resource for healthcare delivery;
vii. Promoting and supporting research into plant medicine to complement allopathic medicine including the commercialization of the research results;
viii. Establishing specialized health centres to promote health tourism

ix. Harnessing recent advances in STI to address health care needs
x. Enhancing local industrial production of some consumables in health care service delivery such as medical disposables.

3.3 Education

The strength of the nation's STI base depends on the quality of education and training in science and mathematics in basic and second cycle schools to produce a critical mass of young people who are well prepared for courses in science, mathematics, engineering and technology at the polytechnics and universities. The quality of the education and training in these tertiary institutions determine the quality of these trained and skilled personnel and therefore the nation's STI capacity. More investments in education and in incentive structures would be required to achieve this. Business as usual policies would not improve science and mathematics teaching in schools, and would not produce qualified students in the numbers required to make a difference. Inadequate numbers of high level jobs for science, mathematics and engineering graduates would continue to discourage the more talented students that are required for education and training in S & T. Effective strategies are required to respond to the challenges mentioned. Leapfrogging the quality and scope of science and mathematics education would be greatly assisted by ICT-driven distance-learning methodology.

Some programmes to drive the vision and mission for education include the following:

i. Ensuring that by the year 2030, 60% of all students in the public universities and 80% of those in the polytechnics and vocational institutions are registered in science and science-related disciplines;

ii. Promoting post-graduate education in scientific disciplines, targeting 10% of the student population in tertiary educational institutions enrolling at the post-graduate level;

iii. Creating special incentives for students and graduates of Science, Technology, Engineering and Mathematics (STEM);

iv. Improving science education at all levels and in all aspects of the educational system, especially at the basic and secondary levels with emphasis on creativity and innovation;

v. Promoting technical and vocational education and training to enhance middle level management in science and technology delivery to all sectors;

vi. Promoting science and technology innovativeness within the educational system;

vii. Increasing the country's capacity in the training of personnel in emerging technologies such as biotechnology, nanotechnology and material science and engineering;

viii. Using the mass media to popularize STI;

ix. Enhancing collaboration between research institutions and universities to train high-level scientific manpower;

x. Ensuring that adult literacy classes include studies into cause and effect relations and how things work;

xi. Facilitating regular review to identify skill gaps in STI (new emerging technologies);

xii. Revamping the practice of industrial attachments for technical, vocational education as well as science, technology and engineering students;

xiii. Devising ICT-driven education and training programmes in science and mathematics in basic and second cycle education;

xiv. reviving the National Science and Technology Museum project which began as far back as 1965 to use it as a major instrument to promote science acculturation nationally. Regional Science and Technology Museums should be built nationally as a major project to promote science and technology education.

3.4 Energy

Ghana needs a supply of sustainable, affordable, safe and reliable energy for domestic and industrial use. Energy must be safely produced, distributed and utilized. Well trained scientists, technologists and technicians are required in adequate numbers to do this. Ghana's main energy supply has come from electricity which is generated from the Akosombo hydroelectric dam and thermal plants. While Ghana prides itself that the engineers, technologists and technicians who produce, distribute and utilize power are Ghanaians, serious interruptions have been common for the past decade or more. This is a big challenge to the nation's capacity to apply science and technology in large scale projects.

Some programmes which will be considered in the short, medium and long term include the following:

i. Promotion of a research and development programme relating to alternate energy sources such as solar energy, biomass, wind and other renewable energy sources to supplement the current traditional energy sources;

ii. Facilitating efforts to acquire and adapt sustainable, safe and economical energy technologies for national development; in particular, work towards attraction into Ghana in the medium–to-long term world-class solar energy systems design and manufacturing capability towards making PV panels ubiquitous and more affordable in Ghana.

iii. Supporting research aimed at upgrading hydropower energy production technology;

iv. Promoting research and development efforts aimed at popularization and dissemination of energy technology suitable for rural development;

v. Promoting public support for energy conservation and encourage private investment in energy technologies;

vi. Encouraging community investment and ownership of energy systems e.g. solar farms, windmills and biomass plants;

vii. Exploiting the utilization of nuclear energy resources for domestic and industrial use.

viii. Developing an integrated petrochemical industry to respond to the oil and gas industry.

3.5 Industry

Ghanaians engage in a wide variety of activities and enterprises which can be classified as industry. A list of these industries will open more eyes as to how a more developed science, technology and innovation capacity can enhance production and processing to increase value addition to increase wealth and create jobs. These industries include cocoa, mining, textile, timber, farming, fishing, aquaculture, crafts, pottery, wood, furniture, tourism, finance and banking, export of banana, citrus pineapple (non-traditional exports), food and beverages.

Some of these industries are rooted in the informal sector and operate with indigenous technologies whose capacities can be enhanced using STI. Evaluation of indigenous technologies in fishing, farming, crafts manufacture, will indicate how this can be done. The role of STI should be to increase the national capacity for industrial production and value-addition. Fish storage and consumption patterns in Ghana before and after cold stores were installed is one example of how new technologies change social and consumption patterns. Oil and Gas exploration opens up new opportunities for Ghanaian industry which require skilled human resource to develop into a new petrochemical industry.

As a largely agricultural country with a wide variety of farm products other than cocoa such as cassava, citrus, pineapple, banana and plantains agri-processing, food and beverages have potentials well beyond their export as the non-traditional commodities. A successful

massive fruit juice industry in Ghana can capture major markets in West Africa and beyond.

Ghana's early industrialization period featured primary manufacturing and secondary manufacturing industries such as radio and television sets and motor vehicle assembly plants. Such initiatives need to be revisited, perhaps within the industrialization plan, but this time with better trained, technologically capable and skilled supporting workforce so that the mistakes that led to the failed state-owned enterprises of earlier years are not repeated.

Some programmes and activities to be pursued include:

i. Strengthening systems and mechanisms for acquisition, assessment, adaptation, adoption and application of essential technologies for industrial activities;
ii. Encouraging R&D activities that develop tools, equipment and machinery for industries;
iii. Encouraging quality assurance in manufacturing;
iv. Promoting S&T activities that would accelerate technology transfer and innovations;
v. Creating incentives to promote investment and support in research and development by the private sector;
vi. Facilitating capacity building in engineering design and manufacturing technology to enhance national development;
vii. Enhancing industrial technology development infrastructure;
viii. Promoting and facilitate recyclable materials technologies, and application to minimize industrial waste in the environment;
ix. Promoting scientific knowledge acquisition and development of technologies in the new and emerging disciplines of biotechnology, materials science, micro-electronic and laser technology;
x. Creating the national capacity to exploit opportunities for innovation addressing climate change;

xi. Establishing industrial parks, innovation centres and business incubators to foster linkages between the knowledge centres (i.e. research institutes and universities) and productive enterprises;

xii. Institutionalizing regular interaction between research institutions/universities and the private sector;

xiii. Incentivizing firms to support industrial attachment programmes for S&T students.

3.6 Trade

To promote STI applications in commercial activities to ensure quality, reliability and efficiency in the delivery of goods and services in conformity with appropriate local and international standards. Some of these activities are listed below:

i. Encouraging the adoption of scientific and technological innovations to ensure effectiveness and efficiency of product output and high quality of products;

ii. Utilizing science and technology in improving national standardization and quality management programmes;

iii. Utilizing science and technology to improve packaging;

iv. Promoting the adoption of standards for the production of goods and services for the local and international markets, including guiding firms through ISO certification procedures.

3.7 Environment

The environment is a source of natural resources, food, medicines and some of the basic necessities of life. It is a source of recreation for improved well-being. As the primary source of the inputs for industry, the environment has to be utilized in a sustainable manner. Its deterioration has been recognized worldwide and its protection has been responsible for the establishment of Environmental Protection

Agencies in Ghana and elsewhere. Application of STI to all aspects of the management of the environment would enhance sustainability. Some of the activities and programmes to apply STI in the management of the environment to maintain and enhance quality and sustainability and to integrate environmental concerns in all development policies include the following:

i. Integrating environmental concerns in all development policies and ensure public understanding of the scientific basis of their actions on the environment;

ii. Encouraging and support science and technology interventions that promote sustainable environmental conservation and management;

iii. Strengthening research and development activities that would promote sustainable development especially of ecosystems and ecological processes;

iv. Developing the STI capacity to monitor, predict and mitigate the adverse effects of natural phenomena such as earthquakes, floods, droughts, desertification and bushfires;

v. Developing an efficient integrated waste management system that applies the principle of waste as a resource.

vi. Promoting the use of clean technologies in production systems.

3.8 Human Settlements

To promote the use of STI in planning and managing human settlements as well as all spatial developments, some STI applications will be required to promote efficient and effective delivery of utilities and services and to integrate planning technologies in the control of urban sprawl. More use will be made of STI applications to establish standards, guides and codes for buildings to ensure durability and integration with the building materials fabrication industry.

Management and efficient delivery of services like water, electricity, disposal of domestic and industrial waste and the operation of local markets have tasked the capacity of the government and city officials to the extent that slums have characterized our cities. More sophisticated management of urbanization and its problems have eluded our governments so far. New solutions must be found in more sophisticated planning and implementation. Government would consider the setting up of centres for the study of urbanization in selected universities to advance the professional management of the city to move national efforts which have so far been more philistine than scientific. Strategies would be formulated, among other things, to:

i.   Encourage the use of STI to minimize the impact of natural disasters;
ii. Encourage, through constant education and legislation, the greening of human settlements;
iii. Encourage the use of STI to establish standards, guides and codes for buildings to ensure durability and integration with the building materials fabrication industry;
iv. Emphasize sound environmental management in human settlement for sustainability of human societies.
v.   .Ensure effective sanitation in human settlements.
vi. Promote the construction of green buildings (or environmentally friendly houses).

3.9 Natural Resources (Land, Minerals, Water, Oil, Gas, Wildlife, etc.),

The primary goals for the application of STI for natural resource exploitation and management are to strengthen the development and extension of technologies and innovations that form the basis for sustainable use of natural resources; enhance local participation in the STI associated with the exploration and exploitation of Ghana's oil and

gas resources; facilitate research and ensure prevention or control of pollution of the environment. There would be strategies formulated to, among other things:

i. Support research in the exploration and sustainable exploitation of mineral resources;
ii. Ensure effective development and utilization of natural resources;
iii. Strengthen the development and extension of technologies and innovations that form the basis for sustainable use of natural resources;
iv. Promote research and measures to protect and conserve biological diversity of the country's ecosystems;

3.10 Science Acculturation

The STI Policy aims also at promoting a culture of science, technology and innovation through public and private awareness campaigns and the development of an information system to enhance the scientific thinking of Ghanaians in their everyday lives. The emphasis in the educational institutions will be on Science, Technology, Engineering and Mathematics (STEM). It would promote and support STI literacy programmes to facilitate the adoption and application of science and technology. Among other things, there would be strategies to:

i. Make science easy to understand and popular by packaging, research findings for dissemination by the mass media and through other channels;
ii. Facilitate the training of human resources for effective STI writing and communication;
iii. Popularize STI through the establishment, investment in, and management of science museums, STI fairs, and in exhibitions to allow public participation in STI activities in all parts of the country.

3.11 Information and Communication Technologies

ICT is a dominant new technology which must be fully popularized and deployed in all sectors of the economy. The STI Policy would aim to promote the use of STI to ensure modern information and communication technologies are available and utilized at all levels of society. Specific ICT strategies would be designed to:

    i.   Ensure STI capabilities exist to integrate ICT into all sectors of the economy including education, industry, agriculture, health and e-governance;

    ii.   Develop a national competence for computer hardware and software engineering and information security;

    iii.   Facilitate the development of a modern ICT infrastructure to improve teaching, learning and research.

    iv.   Disseminate and pursue ICT for development (ICT4D) principles and ideals.

3.12 Building and Construction

Infrastructural development especially in housing is fundamental to the attainment of the national vision. A primary aim in this policy is to develop the STI capacity to support the building and construction sector, including the development of local raw materials and equipment and to encourage their use. Some interventions include:

    i.   Developing the necessary capability in building and construction design, management, execution and production of building and construction material and equipment;

    ii.   Supporting the popularization of appropriate and locally specific building and construction and low-cost materials and technologies;

    iii.   Ensuring the standardization of building, design and construction materials for rationalizing their use and public safety especially in the informal sector;

iv.   Encouraging the training of artisans in the use of local materials and equipment.

v.   Exploiting the potential of digital technology for the design and construction of houses.

3.13 Science, Technology and Innovation and National Security

National security is paramount in ensuring stability and sustainable governance in Ghana. The policy will aim to develop STI capacity for the country's security services to enhance the efficiency and effectiveness in their operations. Some specific interventions include:

i.   Supporting the development of STI to enhance the country's security infrastructure;

ii.   Promoting the use of STI to combat sophisticated crimes,

iii.   Enhancing the teaching, research and application of science and technology in the security services.

iv.   Using STI protect sensitive national infrastructure and installations.

3.14 Nuclear Science and Technology

In line with the efforts to explore the application of all sciences, there will be efforts to exploit a nuclear science and technology for national development. This policy will aim to promote further the peaceful uses of nuclear science and technology in the national development process. Expected interventions include:

i.   Developing the requisite infrastructure and human capacity for nuclear science and technology;

ii. Accelerating the application of nuclear science and technology in all sectors including energy, health, agriculture and industry.

iii. Establishing a national regulatory framework for ionizing and non-ionizing radiations to ensure public safety.

Follow up with planning and investments the decision to develop nuclear energy as an additional source of energy.

3.15 Materials Science and Engineering

Materials Science and Engineering have become the focus of exploring the structures and properties of materials, processing and application of advanced materials for national development. Being a multi-disciplinary derivative of the traditional sciences and engineering, with chemical engineering as the processing tool, material science and engineering serve as the fundamental basis of industrialisation. This Policy will aim to promote and integrate material science and engineering in the national development process. Interventions would be made to:

i. Develop the requisite knowledge base to understand the structures, properties, processing, and the applications of materials systems (Ceramics, Metals, Polymers, Composites, Semiconductors, Biomaterials, Nanomaterials, biomaterials, etc)

ii. Establish and institutionalize materials science and engineering as a core engineering discipline in Technical Education Institutions.

iii. Establish Ghana as a regional hub for high-performance materials systems by acquiring the necessary high-end material synthesis, analysis and testing infrastructure

iv. Establish industrial expertise in chlor-alkali and related basic industrial chemicals

v. Develop advanced metallurgical expertise in foundries and forming technologies and their applications

vi. Establish advanced materials manufacturing systems and capabilities covering the above materials.

3.16 Basic Research

Expanding the frontiers of new fundamental knowledge is a scientific enterprise that thrives on active basic research. And while adhering to the principle of no re-invention of the wheel, researchers will be supported to undertake basic research relevant to socio-economic development. The policy aims also to promote and encourage basic research as the bedrock of scientific and technological innovation. Expected interventions include:

i. Encouraging and support basic research by providing adequate resources;
ii. Acquiring requisite state of the art infrastructure for the furtherance of education, training and research;
iii. Creating incentives for the study of basic science at undergraduate and postgraduate levels;
iv. Educating, training to retain, and motivating sufficient numbers of talented research and technical personnel for basic research;
v. Seeking opportunities for collaboration in education, training and research with partners in the African Union and beyond.
vi. Seeking out known and innovative strategies to utilize fully the special knowledge and skills of willing Ghanaian experts and other Africans in the diaspora.
Promoting excellence in STI by recognizing and honouring exceptional Ghanaian and African experts working locally and abroad.

3.17 Sports and Recreation

Ghana is a sporting nation. The experiences of the leading sporting nations of the world illustrate the huge impact STI could have on sports. The STI policy will also promote scientific and technological

methods which enhance the development of all sports and interventions will be made to:

i. Promote research and development in sports medicine and nutrition, physical education and other disciplines to produce high caliber of sportsmen and sportswomen including the physically challenged;
ii. Facilitate the development of recreation as a health maintenance factor;
iii. Encourage STI courses related to sports at all levels of education.

3.18 Youth Innovation

Every effort will be made in the educational system to popularize, through the mass media, the applications of science, technology and innovation among the youth. Being the heart of the nation, the youth will be groomed and integrated into the National Innovation System.

Specific interventions will be made to:

i. Promote innovation at all levels of the educational system;
ii. Encourage activities that draw on the STI capabilities of the youth such as Science and Mathematics clinics, and computer programming clinics for both girls and boys; and promote STI competition among the youth;
iii. Establish award schemes that reward innovation among the youth;
iv. Provide scholarships for promising science students;
v. Establish mechanisms for encouraging young people to study the sciences;
vi. Initiate mechanisms for early identification of talented young scientists; and
vii. Establish mentoring programmes in STI for the youth.

3.19 Roads and Transport

An efficient modern economy requires a modern and well-developed transportation network. To use STI to improve the road and transportation system and promote more efficient and safe movement of people, goods and services, specific interventions will be made to;

i. Promote R&D in the road and transportation system;
ii. Facilitate the adoption and use of R&D outputs and local innovations for road design and construction;
iii. Encourage investment in local innovation in the transport sector;
iv. Create information management systems for transport companies to improve on service delivery;
v. Develop appropriate scientific human resources for the transportation system.
vi. Encourage, in the medium to long term, the development of capacity of local civil engineering and road construction firms to take up more and more of high-end complex projects such as flyovers and overpasses;
vii. Promote safety on all the transportation networks in the country especially safety of the highways, railways and airways.

3.20 Tourism

As a major source of revenue and job creation, the tourism industry will benefit from the rigourous application of STI to improve service delivery. The industry is a major source of foreign exchange for Ghana. STI applications will aim to enhance such earnings.

Specific interventions will include the following:

i. Promotion of STI in the marketing of Ghana's tourist attractions;
ii. Adoption of relevant technologies in the operations of tourist sites;

iii. Promotion relevant technologies that make Ghana's tourist sites safe and secure.
iv. Design and implementation training schemes to enhance the competence of technical staff of the tourist industry.

3.21 Space Science and Technologies

Ghana aims to become one of the African countries – so far South Africa, Egypt and Nigeria – which have made serious efforts to launch satellites into space. However, the country needs to begin working on the rudiments of space science capacity building. The awareness must be created among stakeholders that space science is not a luxury but rather an endeavour fundamental to a dependable STI base for national development in areas such as weather monitoring and forecasting, environmental surveillance, telecommunications, business and finance.

The programs to be pursued will among others be orientated towards:

i. Assessing existing national infrastructure and capacity for space science and technology;
ii. Building and enhancing national capacity for space science and technology;
iii. Increasing knowledge and understanding in all aspects of space science and technology, including radio astronomy;
iv. Applying space science and technologies to socio economic development of the nation;
v. Connecting to regional and international networks in space science and technology;
vi. Supporting international actions and programmes on space science and technology.

4. CHAPTER: MANAGING SCIENCE, TECHNOLOGY AND INNOVATION POLICY

A sector Ministry in charge of science, technology, and innovation will manage and implement Government's STI policies. This mandate will be executed through the organizations operating under its auspices and where necessary through other relevant organizations. The sector minister being a cabinet member will provide the needed leadership to link with other ministries and organizations for STI application and development in the country. The Ministry of Environment, Science, Technology and Innovation (MESTI) has the following Department and Agencies under it and will work through them for the achievement of its overall goal:

- Council for Scientific and Industrial Research;
- Ghana Atomic Energy Commission;
- Environmental Protection Agency;
- Town and Country Planning Department.

The ministry will be structured with a head of policy planning (with the status equivalent to a Director of the CSIR research institute) who has the appropriate experience to interact with the country's scientific and technical experts as well as with government policymakers. The ministry will have representatives assigned to interact with each of the relevant sector ministries in order to ensure the implementation of the sector STI strategies in Chapter 3.

4.1 Apex STI Body

There will be an apex statutory body established to ensure strong advocacy for STI in the country, to provide STI advice to the Ministry and the President, and to ensure coordination and harmonization of the nation's STI policy and programs. This body would serve as a think tank institution to provide the brain power for national strategic STI

policy formulation. The body would complement the Ministry's efforts to influence STI policies in all sectors.

The Government of Ghana has placed STI at the center of the country's development agenda. STI will be the fulcrum around which the socio-economic development of the country revolves and this will only be possible if the STI System of the country receives uninterrupted attention of the President, supported by a council of eminent scientists including women scientists, engineers, industrialists and other accomplished professionals with a broad mandate to advise the President on Science, Technology and Innovation. Every effort will be made to achieve gender balance.

The Presidential Advisory Council on Science, Technology and Innovation (PACSTI) is envisaged as an independent advisory body, to be situated at the seat of Government, and mandated by the Government of Ghana to provide confidential advice to the President of the Republic on STI issues. Such advice would inform government policy development and decision making, and ensure that STI resides at the center the nation's socio-economic development. PACSTI will be mandated to produce periodic State of the nation's STI reports that will benchmark Ghana's STI performance against international standards of excellence.

The proposed model of PACSTI is based on detailed analysis of different international models. It will be chaired by the President of the Republic of Ghana. The setup of the Presidential Advisory Council on Science, Technology and Innovation will be backed by an Act of Parliament.

- It is expected that the apex STI body will liaise with MESTI to: Provide advice to the President and ministries on STI policy formulation and program design, so that they will best serve the specific needs of the country.

- Provide STI advocacy, so that the voice of the country's STI community will be represented in the country's programs and policies at all levels.
- Ensure coordination and harmonization of the country's STI policies through the establishment of the STI Directorate under the Ministry, so that STI activities are comprehensive, complementary, and reinforcing across all sectors and ministries.
- Provide monitoring and evaluation of the implementation of this STI policy, to ensure that the activities initiated to this end are for the benefit of the Ghanaian society. In this wise, a body or more of experts will be set up under the STI apex body to perform the role of reviewers of the implementation strategies of all STI activities.

4.2 Measuring the Performance of Science, Technology and Innovation

To ensure that the implementation of science and technology is on course for the benefit of the Ghanaian society, Government will put in place mechanisms for monitoring and evaluating the performance of activities initiated.

In this regard, a separate body (or bodies) of experts functioning on part-time basis will be set up to perform the role of reviewers of the implementation strategies of all science and technology activities. The distinguished experts may come from local institutions, the diaspora or may be foreign experts. Incentive schemes will be developed for individuals and institutions identified as contributing positively to the development and promotion of science and technology in the country.

4.3 Promoting the Development and Utilization of STI Capabilities

In line with the vision for science and technology-led economic growth and enhancement in the quality of life, government will take necessary measures to develop fully, national science and technology capabilities to enable it achieve greater productivity and efficiency, and to attain self-reliance in terms of trained skills and technical know-how.

To this end various actions will be carried out in broad terms to create the required capabilities. A comprehensive training programme will be designed and implemented, with special emphasis on indigenous capabilities with respect to adaptation, absorption and mastery of imported technologies, skills and know-how for basic research, research and development, and information management. New and emerging technologies, commercialization and dissemination of research results will be strengthened and expanded.

National education policies will be periodically reviewed by collaborating with the Ministry of Education and other relevant bodies with a view to enabling them to respond to national needs. These reviews will target science education, teacher training, curriculum development, teaching/learning methods, engineering and entrepreneurial skills development, among others.

4.4 Promoting Science and Technology Capacity Building

In view of the fact that Ghana intends to promote and nurture innovative development as its goal, a system will be developed to attract, retrain, motivate and retain indigenous scientific, technical and technological skills and know-how. Deserving scientists, engineers and technologists will be given special recognition through

awards. Remuneration for practitioners of science and technology would be packaged to curtail brain drain.

New approaches to education and training shall be developed to equip researchers to work more effectively in an innovative manner. This will require new curricula and training programmes that are comprehensive, holistic and flexible rather than narrow and discipline-based. Education and training in an innovative and competitive society should not wrap people within constraining specializations, but enable them to participate and adopt problem-solving approaches to social and economic issues within and across disciplinary boundaries.

4.5 Strengthening National Engineering Design and Manufacturing Capacity

Engineering Design and manufacturing is at the centre of all industrial activity. It makes possible the design and production of plant and equipment, capital and consumer engineering products, and provides engineering services to all disciplines and sectors of the economy. No industrialised country has missed out on the engineering design and manufacturing industry. If the Government could get the engineering design and manufacturing industry going, it would have established a strong foundation for the development of a domestic industrial base. Progress cannot be made without a corps of well-motivated skillful engineers and scientists at the forefront of the process of creating a manufacturing base able to design and manufacture capital products. To this end, strategic plant-building technologies must be employed. The acceleration of the mastery of strategic technologies is of prime importance in the industrialization programme. Government will facilitate the establishment of centre(s) of excellence for engineering design and manufacturing, pilot and demonstration plants in selected institutes and departments to promote the development of indigenous capacity and capability in these and other fields. An all-

embracing capacity for industrial design will be established in support of quality presentation at all levels of product development and manufacture. The ministry will also spearhead the establishment of technology incubators and industrial parks to enhance the commercialization of local technologies.

Moreover, the knowledge and skills pre-conditions for development are best created with the establishment of the following:

1. Precision Machining (CAD/CAM/CNC Design)
2. Digital Manufacturing and Applications (Agile Manufacturing)
3. Fundamentals of Physical Metallurgy (Superalloys)
4. Micro-Controllers/Processors Technologies (Hardware Systems)
5. Software Engineering (Embedded Systems)
6. Managing Technical Organizations (Business Leadership)

4.6 Strengthening the Protection of Intellectual and Innovative Property Rights

One of the forward movers of science and technology development is the official recognition of innovation and the need to protect the rights of such innovation for the benefit of society. In this respect, government will encourage and promote science and technology development through the protection and use of intellectual and innovative property rights. This will be achieved through strengthening the system for the protection of intellectual property rights, facilitating the use of industrial and other property rights for the development of science and technology; and establishing and strengthening intellectual and industrial property rights as well as information management systems. As well, the Ministry will take appropriate steps to ensure that innovative ideas in the informal sector when identified are protected. A national system for the registration, protection and management of intellectual property rights will be created. (See 4.6)

4.7 Promoting participation of Women in Science and Technology

Traditionally at all levels of the educational system women have not been encouraged to embrace the learning of science. This has created a lopsided picture of the relative proportions of women and men involved in the learning, teaching and practice of science, engineering, technology and related fields as compared to their male counterparts.

The total enrollment of Science Education for girls at the Senior Secondary School from 2013-2015 is 44,963 as compared to total enrollment for boys of 118,645. The story is no different at the tertiary level where there is low enrolment of students (both lesmales and females) in science programmes. The trends of women enrolment in Science, Technology, Engineering and Mathematics (STEM) programmes at the educational level also affect the R & D human resources in our institutions. The total population of female researchers in the public research institutions is 1,452 versus a male researchers' population of 4,121. In order to improve the ratio towards equalization, Government will take appropriate measures to institute programmes which encourage girls to specialise in STEM at the secondary and higher echelons of the education system. Towards this end, MESTI will design special incentive and motivation packages for female science students.

Further, the ministry will promote innovation in women micro and small enterprises (MSEs) especially in the rural areas. Special programmes will be designed to encourage rural women engaged in micro- and small-scale production to adopt new and appropriate technologies conducive to their fields of operation.

4.8 Promoting International and Local Co-operation and Linkages

The international scene is linked in such a way that exchanges, partnerships, networking and co-operation have become paramount for keeping abreast with the pace of innovation in all sectors of the economy. Given the scope for international co-operation in science and technology at the regional and sub-regional levels, the Government will adopt all necessary measures to consolidate and widen bilateral and multilateral programmes to the benefit of its science and technology programmes, especially the flow of scientific and technological information within the national innovation system. MESTI will lead the way in engaging our development partners and other international actors in the development of Ghana's national innovation system.

4.9 Promoting a Science and Technology Culture

Science and technology culture may be loosely defined as the sum total of a society's concept and attitude to science and technology as expressed in its beliefs, traditional customs and daily occupations. In this respect, the Ghanaian society as a whole has not embraced science and technology and its benefits to any appreciable extent, especially in the conduct of their lives. The lack of science and technology culture hampers the application of STI in industry and limits the benefits obtainable from other areas such as modern medicine. This is evidenced in the prevalence of the use of primitive tools in agriculture, fishing, blacksmithing, construction and other technology intensive occupations. At the social level, explanation of natural phenomena is often sought in superstition.

In order to reverse this trend and speed up the acceptance of science and technology, Government will harness all available resources to create public awareness of the benefits of science and technology and

to seek science and technology based solutions to socio-cultural and economic problems. In health, agriculture, industry, trade, recreation, amongst others, the citizenry will be made to recognize the indispensability of science and technology as tools to better their lives.

5. CHAPTER: MECHANISMS FOR FINANCING STI DEVELOPMENT

The success of a programme for integrating science, technology and innovation into the country's development agenda depends on the establishment of appropriate arrangements for financing the STI development and delivery system. It is important that all sectors of the economy, especially the private sector, realize the importance of science and technology and provide adequate resources to support science and technology activities. The necessary systems should also be put in place to ensure that such resources are utilized optimally and that duplication of activities is avoided, as much as possible.

5.1 Government Efforts in Financing Science and Technology

To ensure the availability of funds at all times to meet the demands of innovation for the benefit of society, Government will:

i. take stock of all existing funding lines established to support development in science and technology and industry with the aim of streamlining them to achieve economies in their operations;

ii. establish the National Science, Technology and Innovation Fund to incorporate support for innovation in its sphere of operations;

iii. encourage the private sector to support the funding for R&D activities, especially to cater for the needs of the micro, small and medium enterprises (MSMEs) which can be nurtured to become the cutting edge for the commercialization of novel products or processes (that is, products of innovation).

iv.   accelerate the allocation of a minimum of 1% of the Gross Domestic Product (GDP) to support the science and technology sector;

v.   institute an attractive tax incentive mechanism for contributors to the instituted funds or directly to R&D activities, but in such a way as not to erode the national tax base;

vi.   encourage the formation of a venture capital (high risk) fund administering authority for the commercialization of new technologies from scientific and technological institutions; and

vii.   encourage public procurement of products and services from S&T institutions as a means of facilitating their promotion.

In all these funding mechanisms, Government will solicit the effective participation and contribution of the private sector as an indispensable partner in the management of science and technology for the socio-economic development of the country.

## 5.2 Private Sector Contribution

The private sector will be encouraged to contribute to financing of STI application and development in Ghana through various schemes. A key strategy will be the initiation of Public-Private Partnerships (PPPs) in the application and development of STI. The private sector will be engaged as interested partners in STI programmes. This is particularly feasible in the commercialization of R&D activities. Where there are substantial innovations, independent companies may be floated to fully commercialise the R&D outputs.

5.3 Other Stakeholders' Contribution

There are other stakeholder institutions, which can make contribution to the financing of STI in the country. For example, the Ghana Education Trust Fund (GET-Fund) can contribute a percentage of the total inflow to STI programmes particularly in the area of high level scientific human resource development. Some of its contribution can be towards increasing the quantum of the Science, Technology and Research Fund (STREFUND) which has been set up to promote R&D in the national innovation system.

The research institutions are also important sources for generating resources for STI application. These institutions will be encouraged to enhance their respective Internally-Generated Funds (IGFs). The sector ministry will institute some matching grants schemes to provide incentives for those R&D institutions showing high performance in this regard.

APPENDIX 1 – THE STI ORGANISATIONAL FRAMEWORK IN GHANA
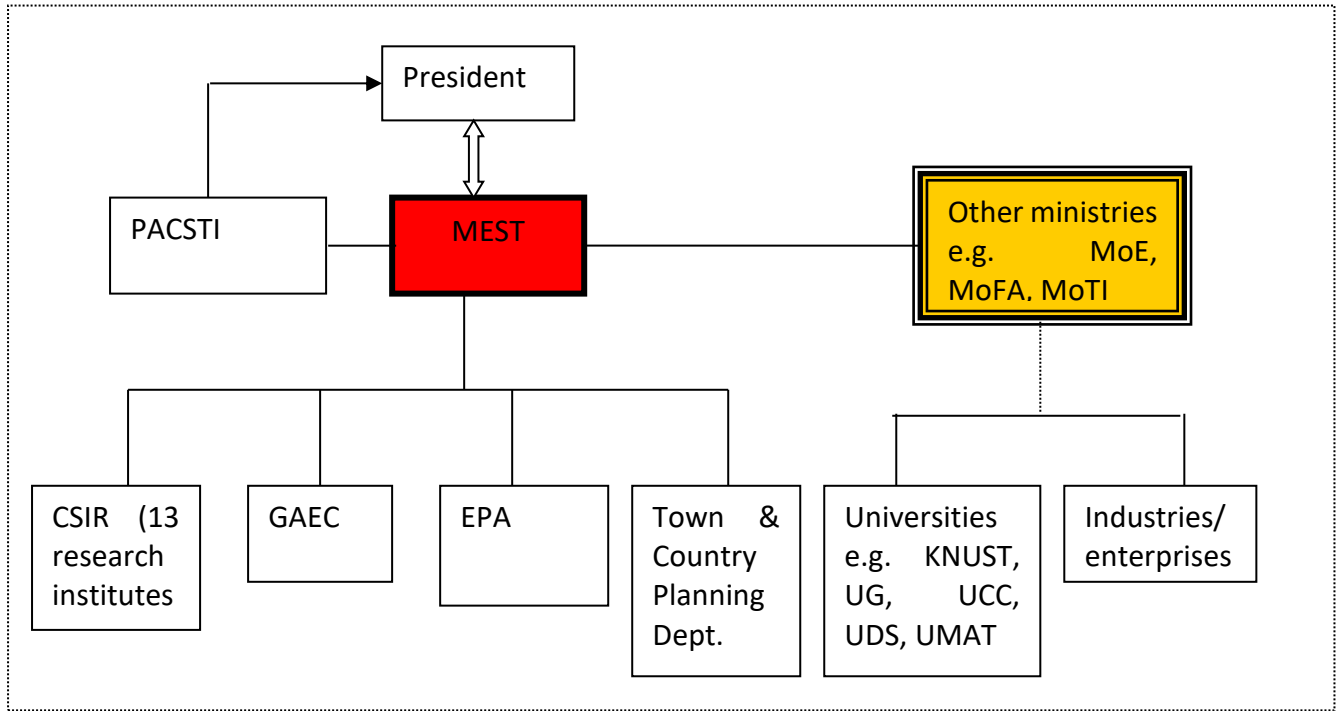
APPENDIX II - SCIENCE AND TECHNOLOGY SUPPORT AND PROMOTION INSTITUTIONS

The understated Government Ministries, Agencies, private sector institutions and Non-Governmental Organizations perform policy formulation, planning, programming, co-ordination, monitoring, evaluation and implementation functions relating principally to their areas of competence in the area of science and technology. The Ministry of Science, Environment and Technology will seek to open science desks in the major ministries.

MAJOR MINISTRIES

National Development Planning Commission
Ministry of Environment, Science, Technology and Innovation
Ministry of Finance
Ministry of Food and Agriculture
Ministry of Fisheries and Aquaculture Development
Ministry of Foreign Affairs and Regional Integration
Ministry of Employment and Social Welfare
Ministry of Mines and Energy
Ministry of Works and Housing
Ministry of Health
Ministry of Education
Ministry of Roads and Transport
Ministry of Lands and Forestry
Ministry of Trade and Industry
Ministry of Communications
Ministry of Local Government and Rural Development
Ministry of Justice and Attorney-General's Department
Ministry of Defence
Ministry of Parliamentary Affairs/Parliamentary Committee on Environment, Science and Technology

MAJOR GOVERNMENT AGENCIES

Architectural and Engineering Services Ltd.
Centre for Scientific Research into Plant Medicine (CSRPM)
Cocoa Research Institute of Ghana (CRIG)
Council for Scientific and Industrial Research (CSIR)
Ghana Revenue Authority
Department of Rural Housing and Cottage Industries
Development and Application of Intermediate Technology (DAPIT)
Electricity Company of Ghana (ECG)
Environmental Protection Agency (EPA)
Fisheries Commission
Food and Drugs Authority
Forestry Commission
Geological Survey Department
Ghana Atomic Energy Commission (GAEC)
Ghana Broadcasting Corporation (GBC)
Ghana Export Promotion Council (GEPC)
Ghana Highway Authority (GHA)
Ghana Institute of Management and Public Administration (GIMPA)
Ghana Investment Promotion Centre (GIPC)
Ghana Regional appropriate Technology Industrial Service (GRATIS)
 Ghana Standards Authority
Ghana Statistical Service (GSS)
Ghana Meteorological Agency
Minerals Commission
National Board for Small Scale Industries (NBSSI)
Pharmacy Council
Technical universities and Polytechnics of Ghana

- Accra Technical University
- Kumasi Technical University
- Takoradi Technical University
- Cape Coast Technical University

- Ho Technical University
- Tamale Technical University
- Sunyani Technical University
- Koforidua Technical University Technical University
- Wa Polytechnic
- Bolgatanga Polytechnic

Public works Department (PWD)
Rural Enterprises Project
State Enterprises Commission (SEC)
Technical Institutes of Ghana
Town and Country Planning Department (TCPD)
Traditional universities of Ghana
- University of Ghana
- Kwame Nkrumah University of Science and Technology
- University of Cape Coast
- University for Development Studies
- University of Education, Winneba
- University of Mines and Technology, Tarkwa
- University of Health and Allied Studies
- University of Professional Studies
- Ghana Institute of Journalism
- Ghana Institute of Management and Public Administration
- University of Energy and Natural Resources
- Over 60 private universities

Volta River Authority (VRA)
Water Resources Commission

NON-GOVERNMENTAL AGENCIES AND INSTITUTIONS

Association of Ghana Industries
Association of Small Scale Industries
Centre for Policy Analysis
Ghana Academy of Arts and Sciences
Ghana Association of Science Teachers
Ghana Biochemical Society
Ghana Chamber of Mines
Ghana Chemical Society
Ghana Geological Society
Ghana Institution of Biology
Ghana Institute of Planners
Ghana Institution of Engineers
Ghana Institute of Physics
Ghana Institute of Surveyors
Ghana Journalist Association
Ghana Medical Association
Ghana National association of Garages
Ghana National Chamber of Commerce
Ghana Registered Nurses Association
Ghana Science Association
Institute of Economic Affairs
Mathematical Association of Ghana
National Union of environmental Non-Governmental Organisations
Pharmaceutical Society of Ghana
Private Enterprise Foundation
Research Staff Association (of the CSIR)
Trades Union Congress
Women in Science and Technology
Ghana Institute of Architect
University Teachers Association of Ghana (UTAG)