The Development of CSIR-Industry Collaborative Blueprint And Implementation Framework

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RISA Research and Innovation Systems for Africa

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Executive Summary

The Council for Scientific and Industrial Research (CSIR) partnered Heritors Labs Limited, asoftware development enclave consulting and product development house, and a hub for Research and Innovation, as a facilitator, and supported by the Research and Innovation Systems for Africa (RISA) Fund of UK to develop this viable model for Industry collaboration for Science,Technology, Innovation and Research (STIR) ecosystem in Ghana. This blueprint developed can be adopted by Research Institutions and Universities to collaborate better with Industry in a way that will benefit these institutions financially from their research outcomes and to put Ghana on a good path for accelerated development.

The document presents key indicators of STI status and indicators of socio-economic development as well as global trends for the impact of science and technology on socio-economic development and concludes with a blueprint for fostering collaboration and innovation within the Ghanaian research and innovation ecosystem for consideration.

The achievements of CSIR covering a range of technologies, products and services which have impacted positively on the activities of various sectors of the Ghanaian economy are presented.

Ghana in its pursuit of economic growth, experiences a great need for science, technology and innovation (STI) skills. Following the example of international counterparts, it is important that the Research institutions (R), Industries (I) and Universities (U) enter into R-I-U agreements as a counter strategy to the growing skills need of the country. An R-I-U collaboration draws on the contributions of all the stakeholders for its success. These contributions do not just take the form of inkind and financial resources, but knowledge as well. The R-I-U collaboration needs industry participation and involvement in the programme as a whole to tap its knowledge base. Industry involvement will clarify the skills need and areas where technology and innovation are needed. More so, industry involvement will help to shape vocationally relevant education matching knowledge, skills and behaviour. R-I-U collaboration programmes in Ghana must therefore be promoted.

A situational analysis of the STI involvement in Ghana's development vis-s-vis the Research-Industry-University collaboration has been undertaken which has led to the identification of four (4) strategic thrusts, with well-defined objectives, targets and robust monitoring and evaluation framework which, when diligently pursued, would enable the STI Ecosystem to improve significantly. A summary of these

thrusts and their activities and targets are as outlined below:

Industry Driven R&D and Technological Innovation

Objective:

To develop and transfer at least one (1) industry-driven technology (of relevance to the local economy) per each Research institution/University per year.

Targets:

To include at least twenty (20) commercially and sustainably viable industry-relevant technologies developed, validated and adopted by industry.

Improve Visibility of the STI Ecosystem

Objective:

To ensure that the activities of the Scientific community is positively visible through regular appearances in the print and electronic media; and enjoys significant goodwill from its identified stakeholders through interactions.

Targets:

At least,

- PPP arrangements established with at least 25 industries
- Increased Stakeholder Engagement and Media Exposure.
- Webometrics ranking of the STI Ecosystem improved to at least the best 10 in five years.

Financial Resources Mobilization

Objective:

To resource the research institutions and universities through: IPR operationalization; entrepreneurial capacity development; attraction of funds from industry for research; and funds for consultancy services and public private partnerships.

Targets:

At least,

- Attraction of funds through submission of winning proposals, bidding for consultancies, sale of research by-products and technology development for industry
- IPR Policy operationalised for effective commercialisation.
- STI Ecosystem Staff trained in relevant entrepreneurial activities.

STI Ecosystem Performance Improvement

Objective:

To enhance performance through sensitization and motivation as well as ensuring a robust and effective Monitoring and Evaluation system.

Targets:

Include

- M&E System enhanced, with adequate staff and resources.
- Conduct annual situational analysis (HR Climate survey) to identify causes of poor attitudes and the lack of motivation amongst the STI Ecosystem and address them.
- Identify professional development needs of the ecosystem and develop and implement training programmes to address them.

The IP Office of the CSIR, the Commercialization Divisions of the CSIR Institutes must work in tandem with the CSIR-TDTC and the CSIR Plus. These bodies can serve as the main drivers in the development and dissemination of marketable technologies. They must play their respective leading roles to tap into the IMVCM processes and to ensure that commercialization does not become just local, but can take advantage of the Commonwealth science and research, innovation, resources, capacities, and infrastructure, as well as the market to thrive.

An inter-ministerial governing body from the following Ministries: Ministry Environment Science Technology and Innovation (MESTI), Ministry of Trade & Industry (MoTI), Ministry of Education (MoE) and Ministry of Finance (MoF) has been suggested. The respective Ministers or their Chief Directors, or Heads of Agencies and Departments of the above Ministries would provide the overarching political oversight. There should be an Implementation Committee made up of stakeholders / technical members to provide technical direction for implementation of the actions. These should be drawn from the CSIR, the Universities, Tertiary Education Sector of the Ministry of Education, Association of Ghana Industries (AGI), Ghana tertiary Education Commission (GTEC), Youth Enterprise Agency (YEA), and Ministry of Trade & Industry.

The Implementation Committee when in place will have to set up Sub-Committees for specific functions and activities. Such Sub-Committees may include:

List of Abbreviations

AGI	Association of Ghana Industries
ASTI	Agricultural Science and Technology Indicators
BHC	British High Commission in Ghana
CEWPAG	Certified Electrical Wiring Professionals Association of Ghana
CRIG	Cocoa Research Institute of Ghana
CSIR	Council for Scientific and Industrial Research
CSIR-ARI	CSIR-Animal Research Institute
CSIR-BRRI	CSIR-Building and Road Research Institute
CSIR-CCST	CSIR-College of Science and Technology
CSIR-CRI	CSIR-Crops Research Institute
CSIR-FORIG	CSIR-Forestry Research Institute of Ghana
CSIR-FRI	CSIR-Food Research Institute
CSIR-IIR	CSIR-Institute of Industrial Research
CSIR-INSTI	CSIR-Institute for Scientific and Technological Information
CSIR-PGRRI	CSIR-Plant Genetic Resources Research Institute
CSIR-OPRI	CSIR-Oil Palm Research Institute
CSIR-SARI	CSIR-Savanna Agriculture Research Institute
CSIR-SRI	CSIR-Soil Research Institute
CSIR-STEPRI	CSIR-Science and Technology Policy Research Institute
CSIR-WRI	CSIR-Water Research Institute
CSRPM	Centre for Scientific Research into Plant Medicine
EDPRS	Economic Development and Poverty Reduction Strategy
GAAS	Ghana Academy of Arts and Sciences
GAEC	Ghana Atomic Energy Commission
GCB	Ghana Cocoa Board
GDP	Gross Domestic Product
GETFund	Ghana Education Trust Fund
GRIs	Government Research Institutes
GTEC	Ghana tertiary Education Commission
IP	Intellectual Property
KATH	Komfo Anokye Teaching Hospital
KBTH	Korle Bu Teaching Hospital
KNUST	Kwame Nkrumah University of Science and Technology (KNUST)
KPIs	Key Performance Indicators
MASTIC	Malaysian Science and Technology Information Centre
M&E	Monitoring and Evaluation
MEST	Ministry of Environment Science and Technology

MESTI	Ministry of Environment Science Technology and Innovation
MODARI	Mapping ODA research and innovation
MOFA	Ministry of Agriculture and Fisheries
MoE	Ministry of Education
MoTI	Ministry of Trade and Industry
MSIT	Ministry of Science and ICT
NCST	National Commission of Science and Technology.
NMIMR	Noguchi Memorial Institute for Medical Research
NRC	National Research Council
OECD	Organization for Economic Co-operation and Development
OGR	Office of Grant and Research
ORID	Office of Research, Innovation and Development
PACST	Presidential Advisory Council on Science and Technology
REP	Rural Enterprises Project
RD&I	Research Development and Innovation
R&D	Research and Development
RISA	Research and Innovation Systems for Africa
R-I-U	Research-Industry-University
SDGs	Sustainable Development Goals
SDF	Skills Development Fund
SMEs	Small- and Medium-sized Enterprises (SMEs)
STI	Science Technology and Innovation
STIR	Science, Technology, Innovation and Research (STIR)
STREFund	S&T Research Endowment Fund
SWOT	Strengths Weaknesses Opportunities and Threats
TDTC	Technology Development and Transfer Center
TTIPS	Technology Transfer and Intellectual Property Services
UG	University of Ghana
UNECA	UN Economic Commission for Africa
UNCTAD	United Nations Conference on Trade and Development
WFTC	Wood and Furniture Testing Centre
YEA	Youth Enterprise Agency

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Chapter 1

The Council For Scientific And Industrial Research (CSIR) Partners With Heritors Labs Limited.

1.1 Introduction

The Council for Scientific and Industrial Research (CSIR) is partnering Heritors Labs Limited, a software development enclave consulting and product development house, and a hub for Research and Innovation. Heritors Labs Ltd. as a facilitator, and supported by the Research and Innovation Systems for Africa (RISA) Fund seeks to develop a viable model for Industry collaboration for Science, Technology, Innovation and Research (STIR) ecosystem in Ghana. This has led to the development of this blueprint which can be adopted by Research Institutions and Universities to collaborate better with Industry in a way that will benefit these institutions financially from their research outcomes and to put Ghana on a good path for accelerated development.

Evidence from experiences of the developed world points to the crucial role STI has played as essential drivers of development. Collaboration between Universities, Research Institutions, and Industries have enabled the transfer of cutting-edge technologies from academia to industries in most countries. This blueprint makes a strong case for a new development agenda for Ghana with STI as the vehicle to drive this development. It establishes a critical role for Ghana's foremost and largest science and technology institution, the CSIR to drive governments agenda such as the Operation Feed Yourself, Eat What Grow and Grow What You Eat, Presidential Initiatives, Planting for Food and Jobs, One District One Factory, One Village One Dam, etc.

The document traces the history of the CSIR, outlining some of the key developmentalstages in its 66-year journey since its establishment. Furthermore, it outlines the current structure of the Institution with particular reference to its vision, mission and functions. The document presents key indicators of STI status and indicators of socio-economic development as well as global trends for the impact of science and technology on socio-economic development and concludes with a blueprint for fostering collaboration and innovation within the Ghanaian research and innovation ecosystem for consideration.

1.2 Establishment of the CSIR

The CSIR was established by NLC Decree 293 of October 10, 1968 amended by NLCD 329 of 1969, and re-established in its present form by CSIR Act 521 on November 26, 1996. The genesis of the Council however, dates back to the erstwhile National Research Council (NRC), which was established by government in August 1958 to organize and coordinate scientific research in Ghana. In 1963, the NRC merged with the former Ghana Academy of Sciences, a statutory learned society. Following a review in 1966, the Academy was reconstituted into, essentially, its original component bodies, namely a national research organization redesignated the CSIR and a learned Society, designated the Ghana Academy of Arts and Sciences.

The distinctive features of the 1996 Act are the emphasis accorded private sector concerns, and the introduction of market principles into the Council's operations through the commercialization of research. In this connection, the Council is expected to generate part of its income through the sale of its products and services, and to institute a system of contract research.

1.3 Structure

The Statutory Governing Council is made up of Chairman and 20 members. They include representatives of selected Ministries (Food and Agriculture; Health; Trade and Industries; Environment, Science, Technology and Innovation) the Universities, various production and commercial associations (Mines, Industry, Commerce, Engineers), Ghana Academy of Arts and Sciences, National Development Planning Commission, CSIR Directors, Senior Staff of CSIR, among others. The Act requires that 40 percent of the membership of the Council be drawn from the private sector.

The Council is answerable to the Ministry of Environment, Science, Technology and Innovation (MESTI).

The CSIR currently has thirteen (13) Research Institutes and operates under CSIR Act 521of 1996. The Director-General is assisted by a Deputy Director-General and three (3) Corporate Directors namely;

- The Deputy Director-General (R&D)
- The Director of Administration
- The Director of Finance
- The Director of Audit

The Head Office of the CSIR is located in the Airport Residential Area, off Agostino Neto Road.

The 13 Research Institutes, each has a Director with semi-autonomous Management Boards.

1.4 Functions (Vision, Mission/ Mandate etc.)

VISION

Using the transforming power of S&T for wealth creation

MISSION

The CSIR is to become the force for accelerated social and economic development of Ghana through examining, exploring and creating Science and Technology catalysts for public and private wealth creation.

MANDATE

To pursue the implementation of government policies on scientific research and development;

- To advise the sector Minister on scientific and technological advances likely to be of importance to national development;
- To encourage coordinated employment of scientific research for the management, utilization and conservation of the natural resources of Ghana in the interest of development;
- To encourage in the national interest scientific and industrial research of importance for development of agriculture, health, medicine, environment, technology and other service sectors and to this end to encourage close linkages with the productive sectors of the economy;
- To coordinate all aspects of scientific research in the country and to ensure that the Council, the research institutes of the Council and other organizations engaged in research in Ghana, coordinate and cooperate in their research efforts;
- To exercise control over the research institutes and project of the Council and to have power after consultation with the Minister to create, reconstitute, merge or dissolve any institute, center, unit or project of the Council;
- To review, monitor and periodically evaluate the work of the institutes administered by the Council in order to ensure that research being carried out by the institute directly benefits identified sectors of the economy and is within the national priorities;
- To institute a system of contract research to ensure that research being carried out in the Council is relevant and cost effective;
- To encourage and promote the commercialization of research results;
- To undertake or collaborate in the collation, publication and dissemination of the results of research and other useful technical information;
- To organize and control services and facilities available to the Council and generally to manage the properties of the Council
- To coordinate human resource development in institutes of the Council and generally to manage the properties of the Council;
- To coordinate human resource development in institutes of the Council and to encourage the training of scientific personnel and research workers through the provision of grants and fellowships;

- To cooperate and liaise with international and local bodies and organizations, in particular, the Universities and the private sector on matters of research; and
- To perform such other functions as may be determined by the Minister.

1.5 Current Approach to Operationalizing Mandate

In an effort to effectively and efficiently fulfil its mandate the CSIR adopted a five-fold approach where the products/ technologies /innovations/ services generated from the research activities are transferred to private sector entities or marketed to the general public through commercialization (CSIR-Plus). Research Scientists assist in training, conducting research and supervising post-graduate students in the CSIR College of Science and Technology (CCST). Finally, the revenue generated from both the CSIR- Plus and the Graduate School is used to support research in emerging and national priority areas. This five-fold approach is illustrated below (figure 1).

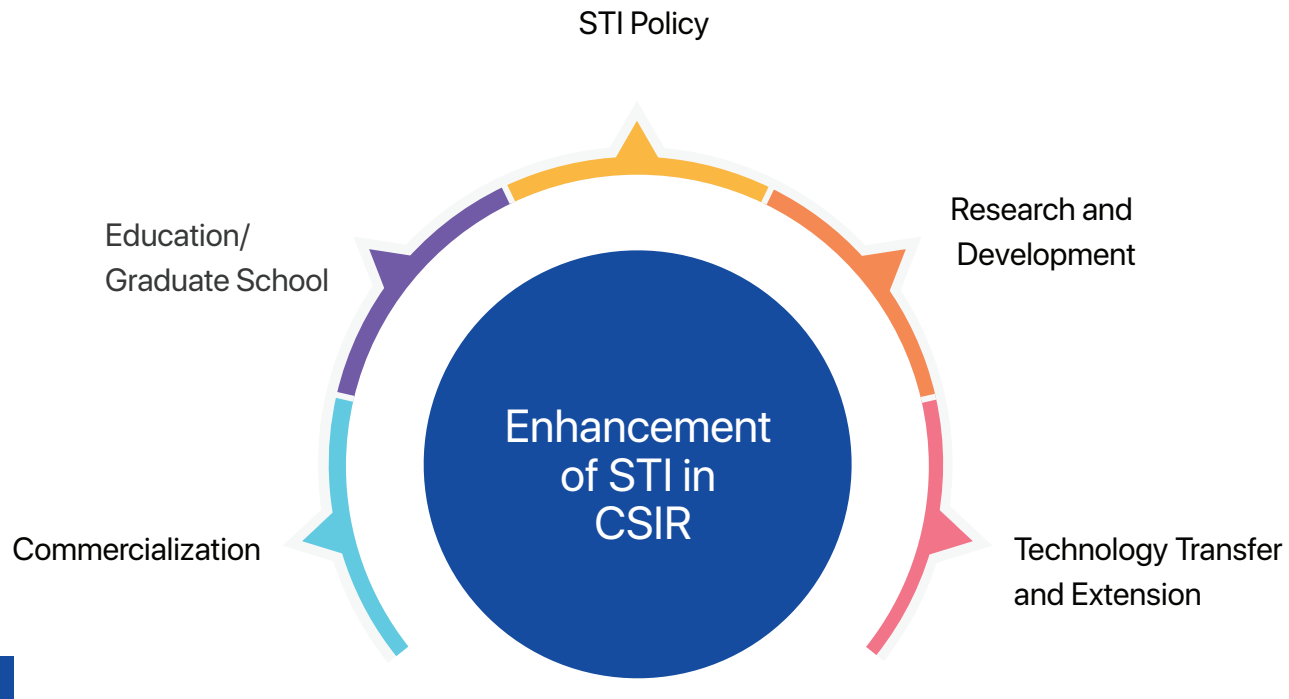

Fig. 1: Five-Fold Approach to Mandate Operationalization

Chapter 2

Comprehensive Assessment of Current State of Collaboration Between Research, Industry and Universities.

2.1 Introduction

Universities serve industry in two ways. They provide the workforce necessary to run industry, and also furnish innovative ideas to start new business ventures. These apparent simplistic relationships do not work so simplistically because of the inherent differences between the two. Universities contribute to the theory whereas industry is restrained by profitability. Therefore, academia and the industry are analogous to two sides of a river that must flow independently. As far as science, technology and engineering disciplines are concerned, creating linkages between the two sides of the river has the potential to contribute to the betterment of both—the industry and academia.

According to the Organization for Economic Co-operation and Development (OECD), industry conducts around two-thirds of R&D in science and technology studies. The remaining 20% of R&D work is carried out by universities, while 10% is carried out by the government. The world's top-ranking universities attract industry funding for their projects and innovations. The pharmaceutical industry is one of the most prominent investors in universities.[1]

The IT industry has also started investing in academies because it has concluded that it is beneficial to spend on students and academia. Exactly 26,355 universities from all over the world are included in a survey carried out in July 2016 that lists the countries arranged by the number of universities in the top rankings.[2] With this statistical data, it can be concluded that collaboration between industry and academia is on the rise. However, such collaborations are not experienced in Ghana. And the question is WHY?

2.2 The CSIR Technologies developed and transferred

The CSIR has established the Technology Development and Transfer Centre (TDTC) since 2018. The CSIR-TDTC is well positioned to engage Research Scientists and Research Technologists to respond effectively to the technology demands from the private sector creating a system or platform for intensive research-industry interaction and facilitating commercialization along with the promotion of all technologies developed by the CSIR.

The CSIR-Technology Development Transfer Centre is a key pillar in the structure for commercialization and technology transfer of technologies and innovations from the CSIR Research Institutes to end-users in the private sector. The CSIR-TDTC was formally incorporated under the Companies Act, 1963 (Act 179) with liability limited by guarantee on the 17th of September, 2018 with its Board of Directors inaugurated on 21st May, 2020. The vision is to become a Centre of Excellence that uses the transforming power of Science, Technology and Innovation (STI) for wealth creation through effective linkages between Research and Industry; the mission being to: **(a)** engage the private sector in partnerships for technology development, appropriation and transfer from the CSIR to industry, **(b)** encourage CSIR Research Scientists to respond effectively to the technology demands from the private sector, **(c)** create a system or platform for intensive research-industry interaction including but not limited to organization of technology fairs, business meetings and online discussions via a dedicated website, and, **(d)** facilitate commercialization of all technologies developed by the CSIR.

2.3 The Office of Research, Innovation and Development (ORID), UG,Legon.[3]

As part of the drive to promote the University of Ghana as an institution of Research and Higher Learning, the University Council decided that starting from the 2008-2009 academic year, a portion of the University's budget shall be earmarked to encourage and promote cutting edge research from faculty members. This is the research support arm of the University of Ghana. The mission of ORID is to promote, coordinate and facilitate research activities in the University, and lead the development of the University's strategic plans.

At ORID, the Pro Vice-Chancellor leads the University's mission to intensify research; consequently, ORID has progressively built strong research support structures and networks in a bid to achieve its mandate. Research management services at ORID comprise:

- Pre- and Post-Award Services (PPA)
- Capacity Development Services (CaD)
- Technology Transfer and Intellectual Property Services (TTIPs)
- Research Performance Services (RePs)
- Publication, Dissemination and Translation (PDT)
- Human and Animal Research Ethics Services (HARES)
- Accounts Services

ORID maintains satellite offices for human and animal research ethics at the following locations;

- Noguchi Memorial Institute for Medical Research (NMIMR)
- College of Health Sciences – Korle-bu
- Institute for Social, Statistical and Economic Research (ISSER)
- College of Basic and Applied Sciences

As part of the continuous process of re-defining the University of Ghana as a research- driven university and encouraging its faculty members to actively engage in research activities that would enhance the image of UG, ORID has the responsibility of announcing a Call for Proposals every year; with support from the University of Ghana Research Fund (UGRF). In addition to doing cutting edge research, it is the expectation that UG will be able to fund projects that are capable of addressing pressing national and developmental issues and offer recommendations that would be relevant to policy makers and all stake holders. A total of eight (8) Calls for Proposals have been announced since the 2008-2009 academic year and sixty-three research projects have so

far received funding.

Proposals are reviewed based on the following criteria:

- Relevance of Research Question
- Scientific Merit of Methods, Design and Analytical Framework
- Potential to Impact Policy
- Justification for Resources
- Capability of Research Team

The Intellectual Property and Technology Transfer Services (TTIPS) team formerly known as the Technology Development and Transfer Centre, manages and leads the University's intellectual property and technology transfer activities, with specific emphasis on developing innovative mechanisms for the University's engagement with industry. Their activities are geared towards internal stakeholders (i.e. researchers, staff, students, etc.) and external stakeholders (comprising entrepreneurs, industry, government agencies, investors, etc.). TTIPS work with researchers, staff and students at the University to help develop their ideas and novel research into new businesses, products or services. TTIPS also help faculty, staff and students to manage inventions and technologies that may have societal and/or economic impact, with or without commercialization.

Activities of TTIPS include

i. Explore opportunities for collaboration between UG academia and industry in finding solutions to business/societal problems

ii. Promote research partnerships between UG academia, students and industry

iii. Work with the Pre and Post Award Team to develop, review and negotiate

vi. Create awareness on intellectual property and technology transfer

v. Receive intellectual property disclosures

vi. Evaluate disclosures for their novelty, commercial potential, requirements for development

vii. Protect intellectual property through patents and other appropriate forms of protection

viii. Facilitate the transfer of technologies from the University

ix. Manage the licensing process

x. Distribute royalties and other revenue from commercialization

xi. Maintain an inventory of the University's intellectual assets.

2.4 The Office of Grant and Research (OGR), KNUST, Kumasi.[4]

The Office of Grants & Research (OGR) exists to serve as a centralized university office for externally funded research. The Office is to provide research and grant administration support services to sponsored research activities in KNUST. The Office has overall responsibility to recruit, retain, coordinate, monitor and evaluate the activities of researchers and garner important research infrastructure and funding for the entire university.

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The OGR works with existing or recruited research administrative staff in all the Colleges to coordinate the university's research training opportunities. OGR seeks to support faculty, staff, and students in their efforts to seek, secure, and manage extramural funding in the most accurate and efficient manner.

The Vision of OGR is to be a Centre of Excellence for research support services facilitating a stimulated, well supported, accountable and expanded research enterprise at KNUST and beyond. The Mission is to provide the needed infrastructure and training to ensure the widespread availability of support and expertise in research administration and management. To achieve this, OGR undertakes to:

- Build research management expertise of staff
- Establish and standardize processes and practices in research administration
- Address the needs of researchers throughout the research process
- Provide the necessary training for researchers
- Assist in obtaining the necessary resources for research
- Facilitate valuable partnerships that will enhance the institution's research agenda
- Ensure protection of the university's interests
- Ensure accountability to external funding sources

KNUST is involved in research across various disciplines cutting across subject areas such as health, agriculture, engineering, physical sciences, humanities and business. All members of the KNUST community are involved in creating and supporting the creation of new knowledge. Research is conducted in all departments and colleges as well as in the various research institutes and centres.

OGR Values are as indicated in figure 2

Fig 2. The Values of OGR, KNUST, Kumasi

Funding Sources and Databases include

- Grants.gov
- Fogarty International Center
- AGRA
- Bill and Melinda Gates Foundation
- DFID
- DFG (Germany)
- European Commission
- Ford Foundation
- International Foundation for Science
- Royal Society of UK
- National Institute of Health
- Netherlands University Foundation for International Cooperation (NUFFIC)
- Norwegian Agency for Development (NORAD)
- United States Fish and Wildlife Service
- USAID
- VW Foundation
- Wellcome Trust
- WHO
- 3rd World Academy of Sciences

2.5 Current state of collaboration between Research, Industry & Universities in Ghana.

The CSIR has collaborated with the universities for many years. Scientists from the CSIR help in the supervision of B.Sc., M.Sc. MPhil and PhD project works and theses. CSIR scientists teach part-time at the various universities in the country. The students' use the facilities of the CSIR such as laboratories and their equipment, field instruments, farm machinery, workshops and libraries. They also come on attachment to the Institutes of the CSIR.

The CSIR Institutes have been using their expertise and state-of-the-art equipment and facilities which include the ones in food security, food safety and food sovereignty, food processing and analysis, water science, seed production, and, building and road infrastructure to play major roles in manpower development through training programmes for students from tertiary institutions. There are also analytical laboratories for chemistry, microbiology, biochemistry, toxicology and nutrition, housed in spacious ultra-modern buildings. There are special laboratories for fish, cassava and cereals. There are well equipped pilot plants for specific commodities, and general ones with operational wet and dry processing lines. The laboratories, some of which are accredited for international recognition of some of the analytical methods, have state-of the-art equipment for high quality results.

The relationship with the Universities, so far, have been based only on formal requests that are in most cases not supported with adequate remuneration. Every year students from all the universities request attachment with the CSIR, in partial fulfillment of their various University degree programmes. There is the need for formal MOU to spell out all details concerning the specific areas of collaboration.

This should take into account the following:

- CSIR ability to handle specific number of students per year
- Agreed costs of the use of facilities and materials
- Co-supervision on students' safety and conduct whilst working in the laboratories
- Joint ownership of publication and technologies developed.

The mission of CSIR-TDTC is effectively reflected in its objects of Incorporation stated as:

- Provide a platform for commercialization of research outputs of CSIR institutes;
- Promotion of interaction between researchers and entrepreneurs for technology development and adoption;
- Any other related business.

In accordance with its mandate the CSIR-TDTC has and continues to engage in activities leading to partnerships and possible commercialization of technologies developed by CSIR Institutes with the industry.

Chapter 3

Collaboration Between Research, Industry and Universities Outside Ghana.

3.1 Introduction

South Korea's per capita GDP has surged from $79 in 1960 to $32,237 in 2022. The Korean economy's development and growth have come in stages, from labor-intensive to capital-intensive, and then to science and technology-driven economy. In 2022, services contributed around 58.03 percent to South Korea's gross domestic product (GDP), while 31.73 percent came from its industry sector, and a little less than 2 percent of the GDP was generated by the country's agriculture sector. South Korea relies upon exports to fuel the growth of its economy, with finished products such as electronics, textiles, ships, automobiles, and steel being some of its most important exports.

The Government of India has stressed the need to enunciate a policy to synergize science, technology and innovation and has also established the National Innovation Council. The STI Policy 2013 was in furtherance of these pronouncements. It aimed to bring fresh perspectives to bear on innovation in the Indian context. India is ranked 5th in world's GDP rankings in 2024.

In 2022, the share of agriculture in Malaysia's GDP was around 8.92 percent, industry contributed approximately 39.1 percent and the services sector contributed about 50.93 percent. The 2020 Report presents Malaysia's performance in STI across a number of areas including human capital development; public awareness; ICT; R&D investment and research workforce; public sector investment in R&D; innovation in manufacturing and services sectors; energy and green technologies; bibliometrics; IP rights; and commercialization and returns on R&D.[5]

3.2 Analysis of best practices from other countries with successful Research-Industry-Universities collaboration

3.2.1 Korea's Transformational Change through Science and Technology

Korea set up a unique STI governance structure to provide STI strategic directions, align plans and budgets and articulated and monitored interventions across the whole of government. The particularity of this structure lies notably in the powerful mandate of the Presidential Advisory Council on Science and Technology (PACST) and the Ministry of Science and ICT (MSIT) in the cross-governmental co-ordination of the STI system via its Science, Technology and Innovation Office (hereafter, "STI Office"). This "control tower" played prominent role in developing five-year Basic Plan and aligning sectoral Ministries' midterm and annual plans with it, as well as in the annual budgeting review of research and development (R&D) programmes and their monitoring and evaluation. This governance has been instrumental in ensuring strategic coherence during a period of rapid expansion of the Korean STI system and the shift from a position of fast follower to that of scientific and technological leader in some key high-growth areas.[6]

This STI governance structure is now confronted, however, with two main issues that call for reforms. Firstly, the system's growth calls into question the sustainability of the current centralised co-ordination mechanisms, particularly when more flexible and inclusive governance is required to cope with a turbulent and complex environment. Secondly, like in many other advanced economies, the need to

to address growing societal challenges requires more issue-based and integrated co-ordination mechanisms that articulate for each challenge the strategic, planning and implementation functions of governance, with direct and continuous interactions between the main decision makers and stakeholders in each challenge area. A key element of agile governance is the integration of strategy throughout the policy cycle to attain specific goals rather than a sequential process characterised by successive functional stages with their own actors and processes. While there are numerous experimentations with new forms of governance and policy making in many countries, notably around the mission-oriented policy approach, no country has yet fully implemented "third generation" governance. Building on the strengths of its existing governance structure, Korea can become a front-runner in this respect.

There were other national dirigiste planning mechanisms, such as the five-year Technology Promotion Plans. Although they played important roles in gradually building a more self-sufficient STI system that relied upon national knowledge and innovation resources and capabilities, government STI plans and interventions still depended significantly on companies' demand and remained subordinated to economic and industrial development policies. The Government Research Institutes (GRIs) also played a major role in absorbing key foreign technologies and transmitting them to large Korean conglomerates. Private firms also received significant guidance and support from state authorities via subsidised loans, specific licences to enter targeted industries and protective regulations. The benefits of these new technologies and associated learning partially trickled down to other parts of industry through backward linkages and long-term production networks with local small- and medium-sized enterprises (SMEs).[6]

Creating the Framework Act on Science and Technology in 2001 was a key milestone in elaborating the Korean STI governance system. It provided the legal basis for the main organisations and mechanisms to centrally co-ordinate all STI-related policies. Since then, it has been amended several times and implemented through a multiplication of new or reformed funding bodies, enforcement decrees, regulations and programmes. It has also been progressively complemented by various other laws in specific areas (evaluation, management of agencies, etc.).

Korea has a well-established three-tier governance structure composed of dedicated institutions with clear legal mandates to perform the essential functions necessary to steer, co-ordinate and implement STI policies. As is typical of advanced economies, the Korean STI system is composed of three main levels of governance as shown in Figure 2.

These are:

1. Strategic orientation/agenda setting: the level of the executive and legislative branches of government where the strategic framework guiding STI activities is developed.

2. Co-ordination and programming: the level of the individual ministries or "administrations".

3. Policy implementation: the level of funding agencies (also known as intermediary or management agencies) which implement policy on behalf of the ministries.

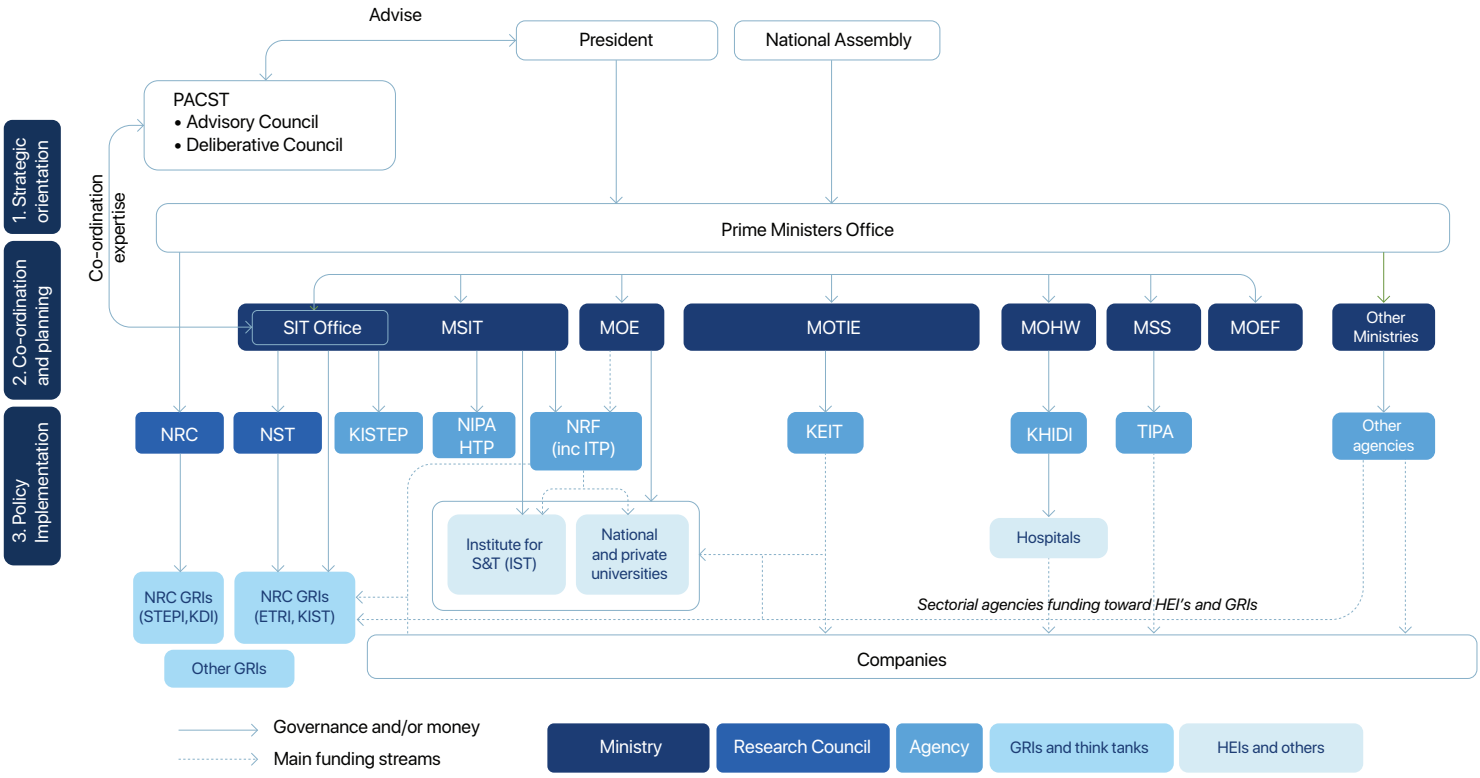

Fig. 3 Korea's STI Governance Structure

Note: Full names of institutions here in descending order: Presidential Advisory Council on Science and Technology (PACST), Ministry of Science and ICT (MSIT), Ministry of Education (MOE), Ministry of Trade, Industry and Energy (MOTIE), Ministry of Health and Welfare (MOHW), Ministry of SMEs and Start-ups (MSS), Ministry of Oceans and Fisheries (MOF), National Research Council for Economics, Humanities and Social Sciences (NRC), National Research Council for Science and Technology (NST), National IT Industry and Promotion Agency (NIPA), Institute of Information and Communications Technology Planning and Evaluation (IITP), National Research Foundation (NRF), Korea Evaluation Institute of Industrial Technology (KEIT), Korea Health Industry Development Institute (KHIDI), Korea Technology and Information Promotion Agency for SMES (TIPA), Korea Institute of S&T Evaluation and Planning (KISTEP), Korea Institute for Industrial Economics and Trade (KIET). Source: OECD based on desk research and stakeholder interviews.

The organisations that perform R&D and/or innovation such as the universities, public research institutes, companies and others, such as hospitals, farmers, etc. form a fourth level that receives funding and associated strategic orientations and conducts activities to generate impact.[6]

Following this typical structure of STI systems, Figure 3 presents the Korean STI governance structure across the six ministries and ten agencies that fund and operate significant amounts of R&D in Korea. A more complete picture would include a far greater number of ministries and agencies that develop policies and manage R&D programmes (Figure 4).

In KRW 100 millions (Korea won)

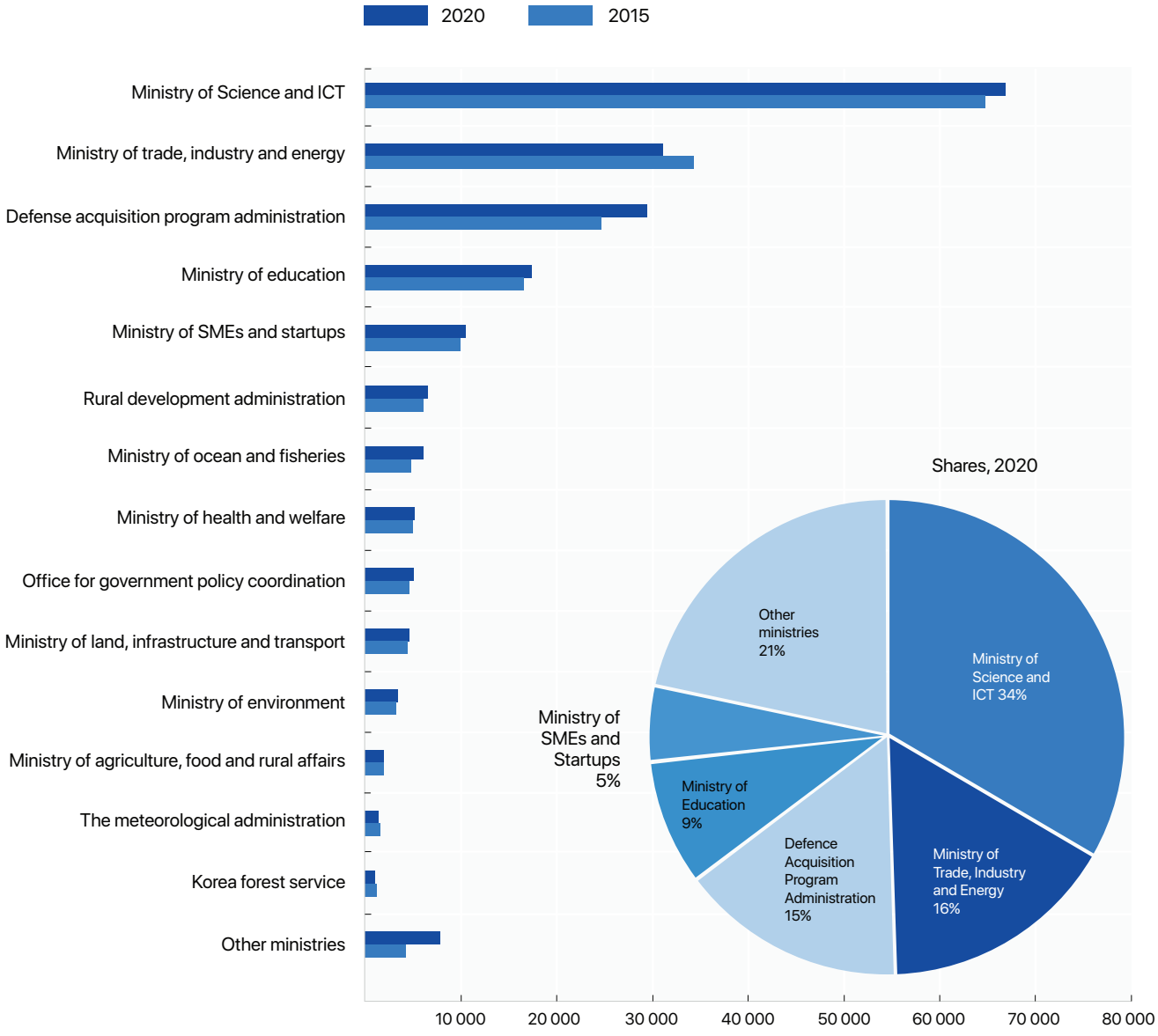

Fig. 4 Trends in implementation of national R&D programmes by ministry, 2019 and 2023

3.2.2 Malaysia's Transformational Change through Science and Technology

The STI system of Malaysia is structured according to a framework of four important pillars utilizing the concept of National Innovation System to better understand the STI ecosystem as follows:

Pillar 1 (Basic Supporting Environment)
Education, public awareness and digital infrastructure are considered as the enablers that serve as the foundation to promote and support STI development.

Pillar 2 (Public and Private Investments)
Includes investments by both the government and industry in funding R&D and other innovation-related activities.

Pillar 3 (Industrial Development)
Evaluates the innovation, knowledge and technological content of STI within the industrial sector.

Table 1. Key Findings: Malaysian STI Indicator Reports 2010, 2013, 2016

Aspects	2010	2013	2016
Education in S&T	• Additional Mathematics is the most registered subject among science stream at SPM between 2005-2009. • A decrease in the number of registered students for Science courses at STPM. • The number of enrolment and graduations in S&T at undergraduate and postgraduate levels in the public universities has remain unchanged over the years. • Female outnumbered male students at the undergraduate level (except in Technical fields] between 2008- 2009, but males outnumbered females at PhD level.	• Mathematics is the most registered subject at SPM between 2008. 2012. • A decrease in the number of registered students for Science courses in STPM. • Lower enrolments in Science courses compared to non- Science courses at the undergraduate and postgraduate levels.	• The number of enrolments for Science and Mathematics at SPM level has increased since 2008 • At STPM level, the number of registrations In Science, Mathematics and Technology subjects has generally decreased • At public and private universities, the number of enrolments for Science courses is consistently less than that of non- Science courses at the undergraduate and postgraduate levels.

Public Awareness of S&T	• Malaysians perceived themselves as between slightly to moderately interested in S&T issues surveyed. • Malaysians perceived themselves as between poor and average in terms of knowledge of SAT. • Malaysians have consistent positive attitude towards S&T. • Malaysia lags behind USA, Europe and South Kores on their understanding of S&T.	• Malaysians viewed S&T as having a positive Impact on individual enjoyment of life, • public health, standard of living and working conditions. • Malaysians have consistent positive attitude towards S&T. • Malaysia lags behind USA, Europe and South Korea on their understanding of S&T.	• Malaysians are found to be either interested or very interested in the STI issues surveyed in 2014. • The number of Malaysians who are very Interested in selected STI issues are much fewer in comparison to the USA and the EU respondents. • The average public knowledge of STI in Malaysia has been below 50%.
Human Resource in S&T	• A decrease in headcount of R&D personnel and FTE for private sector. • An Increase in FTE for the HI.Is. • An increase in participation of women in R&D.	• An increase in headcount of R&D personnel with the highest headcount in 2011. • A marked increase in researchers with Master's and PhD degrees • A steady increase in participation of women in R&D.	• The number of researchers has significantly increased since 2008. • The total R&D personnel stood at 114,539 persons whereas the ratio of researchers to 10,000 workforces was 60.7 in 2014. • Researchers with Master's degree surged more than two-fold from 31.3% in 2012 to 61.7% In 2014 while the proportion of researchers with PhD degree reduced.

Malaysia's STI capacity building has been on the upward trajectory for more than three decades. This uninterrupted attention to building capacity and capabilities is manifested in the nation's rise in several STI indicators as reported in the series of National STI Indicators Report published by Malaysian Science and Technology Information Centre (MASTIC), Ministry of Science, Technology and Innovation (MOSTI) since 1994. The 2020 Report – the 10th edition in this series of reports – presents Malaysia's performance in STI across a number of areas including human capital development; public awareness; ICT; R&D investment and research workforce; public sector investment in R&D; innovation in manufacturing and services sectors; energy and green technologies; bibliometrics; IP rights; and commercialization and returns on R&D. Their latest global rankings are commendable as evident in the international surveys undertaken by Concept Innovation and Strategy (CIS), the Global Innovation Index (GII), and the Global Connectivity Index (GCI).[7] Identifying the critical areas of strength and weakness of the STI ecosystem are essential. Tracking the overall progress of the STI indicators (based on the previous STI reports) from 2010 to 2016 shows that Malaysia has been progressing over the years. The key findings of the progress and gaps are self-explanatory in Table 1, which does not require further explanation.

3.2.3 Rwanda's Transformational Change through Science and Technology

Rwanda's guiding policy document, Vision 2020, sets ambitious goals and targets for the country's socio-economic transformation, including raising annual per capita income from $200 to $900, and halving the poverty rate. Science, technology, and innovation (STI) represent –indispensable tools for helping Rwanda achieve these targets. STI in the form of improved crop varieties, better trained medical professionals, and enhanced local manufacturing capacity constitute vital inputs to social and economic progress in Rwanda. However, STI have been chronically underutilized as tools for development. The 2005 STI Policy[8] aimed to provide a framework for boosting the contribution of STI to Vision 2020 achievement.

In April 2013, the Ministry of Education (MINEDUC) and its Directorate of Science, Technology, and Research (DSTR) initiated a review of the 2005 STI Policy in partnership with the UN Economic Commission for Africa (UNECA). MINEDUC and UNECA invited the Global Knowledge Initiative, an international non-profit organization that specializes in promoting STI for development, with support from a local consultant, to perform the review. Specifically, the review team was asked to evaluate how the STI Policy's objectives have been implemented on the ground in Rwanda, identify specific successes or gaps in implementation, and make recommendations for a possible update of the Rwanda STI Policy itself. MINEDUC and UNECA facilitated the review process by providing historical background on the STI Policy and its implementation; assisting in outreach to key stakeholders for interviews; and hosting two stakeholder workshops (May and June 2013) that informed the review process.

The review of the 2005 STI Policy is warranted at this juncture for a number of reasons.
First, 2013 represents a rough mid-point between the introduction of the policy in 2005, and the culmination of Vision 2020. STI proponents need to understand what has and

has not been working in terms of STI Policy implementation to effectively course-correct before the 2020 horizon. Second, the STI Policy was authored before Rwanda introduced the rigorous planning and benchmarking processes featured in national planning instruments such as the Economic Development and Poverty Reduction Strategy (EDPRS). The STI Policy does not include an actionable implementation plan or monitoring and evaluation (M&E) framework, which has become a mainstay in Rwanda's policy planning process in the years since 2005. This review offered an important pivot point from which they were introduced a clear implementation plan and targets for progress. Indeed, the policy review was recommended to be immediately followed up with an update of the STI Policy and the crafting of an STI Policy strategic implementation plan, inclusive of an M&E framework. This work was to be led by MINEDUC with support from UNECA and the National Commission of Science and Technology (NCST).[8]

Taking a systems-based approach, the four-person research team looked across and within four essential and inter-related pillars of STI: Knowledge Acquisition, Knowledge Creation, Knowledge Transfer, and Innovation Culture. The four-pillar structure, which mirrors the organization of the STI Policy, and the major trends and findings for each are listed below. The findings and considerations for STI Policy reform were designed both to prompt informed discussion during a June 2013 Policy Dialogue, and served as a springboard toward longer-term strategy formulation.

STI Policy Pillar I: Knowledge Acquisition

- Rwanda characterized by high-level commitment to STI-based education with
- Women and girls achieving increased access to STI-based education and careers.
- Lack of practical exposure through STI-based education hinders relevance an employability of graduates.

STI Policy Pillar II: Knowledge Creation

- Agricultural research illuminates how Knowledge Creation can accelerate sectoral development
- Sub-optimal incentives and metrics for research impede research productivity
- Mismatch between research outputs and market needs hinders potential impact STI Policy Pillar III: Knowledge Transfer
- Inadequate commercialization and communication of research results hinders potential benefits
- Interaction with global knowledge network could be strengthened
- Boosting opportunities for industrial attachment and mentorship for students a high priority across sectors

STI Policy Pillar IV: Innovation Culture

- Growing constellation of innovation and entrepreneurship programs means thinly spread resources and duplication of effort
- Insufficiency of graduates' soft skills, in addition to technical skills, hinders business innovation
- Against a history of limited engagement, substantial scope to activate meaningful public-private partnerships. Policy Evaluation Report[9].

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The four-pillar structure provided a framework for analysis that maintained consistency with the policy.

Chapter 4

Framework for Skill Sharing, Knowledge Transfer, And IP Co-creation Between CSIR Research Institutes, Universities and Industry

4.1 Introduction

The achievements of CSIR cover a range of technologies, products and services, which impact positively on the activities of various sectors of the economy. The CSIR has contributed to the efforts by Ghana in attaining some of the targets, events and actions of the Sustainable Development Goals (SDGs) (figure 5) with specific reference to SDGs 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15 and 17.

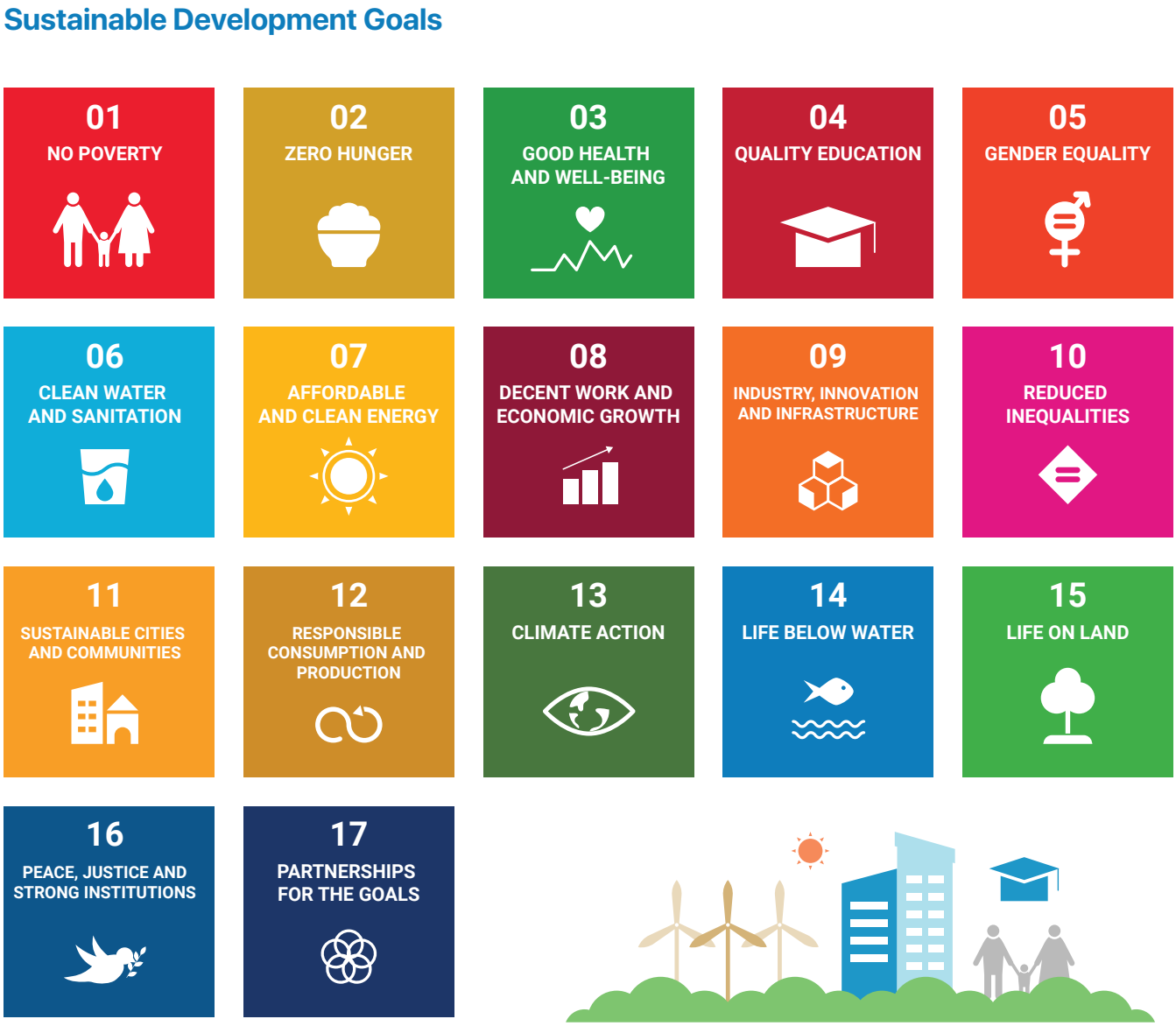


Fig 5. Sustainable Development Goals

4.2 Some highlighted contributions of CSIR to the SDGs through its developed technologies.[10]

SDG 1 & 2

No poverty and Zero hunger respectively **(Eradicate extreme hunger and poverty).** The CSIR has contributed immensely to eradicating extreme hunger and poverty through agricultural interventions such as high-yielding, pest and disease resistant crop varieties and production practices resulting in between 43% and 500% increase in the production of some food and industrial crops which amount to billions of cedis.

These high yielding pest resistant crop varieties and developed production technologies include:

Cereals: Four varieties of Quality Protein Maize (QPM), and yellow QPM for the poultry industry; NERICA rice lines and the Sikamo variety whose quality compares favorably with the imported long grain rice.

Legumes: 6 Cowpea varieties, 5 Soybean varieties and 6 Groundnut (Rosette resistant) varieties all high yielding and disease resistant have been released to farmers.

Roots, Tubers, Plantain and Bananas: 7 varieties of cassava; 3 varieties of yam and 8 varieties of sweet potato; one plantain and one banana variety each.

Tree Crops: Oil palm planting materials with a 500% increase in fresh fruit bunch yields with oil yields of 3.75 - 4.25 tons per hectare; the coconut pollen requirements of Ghana; 2 varieties of cotton.

Biological control: cassava and mango mealy bugs and the 'Acheampong' weed are being controlled using the biological agent Pareuchaetes pseudoinsulata. Innovation in the use of jatropha seed oil and groundnut oil combination, black pepper powder, neem wood ash and ordinary wood ash to control maize and cowpea storage pests

Livestock: Development of Newcastle vaccine which saves between 2.8 and 4 million birds annually; development of Nucleus broiler (ARIBRO) population i.e impacting positively on foreign exchange cash savings to the nation; improved variety of the Nile tilapia which grows 20% faster than the wild stocks.

SDG 3

Good health and well-being **(Combat HIV/AIDS, malaria and other diseases).**

- Technology for the control of vectors/intermediate hosts of water-related disease such as bilharzia, malaria and river blindness (Onchocerciasis) in humans and the subsequent liberation of oncho-infested areas for human habitation and agricultural development.
- Promoting the use of alfalfa as a food supplement to HIV/AIDS patients
- Technology for the use of Groundnut to help in regulating blood lipid
- Assist Traditional Medicine Practitioners to establish their own medicinal plant farms. The total income in this public good research cannot easily be quantified in monetary terms.

SDG 3 & 4

Good health and well-being & Quality Education **(Training. Improve maternal health. Reducing the maternal mortality rate by three-quarters)**.

The research conducted by the CSIR has helped to improve maternal health and create food safety awareness through:

- Development and Application of Hazard Analysis Critical Control Point (HACCP) Systems for Food Quality Assurance has improved the quality of food produced by traditional small and medium-scale enterprises (fermented foods, fish and street foods).
- Training quality control officers and technical staff of various industries in the microbiological safety and quality control of foods has led to improvement in the quality of manufactured food products and has automatically impacted on the health and productivity of the population.
- Aflatoxin Research: The screening of raw and processed foods has generated data on mycotoxin levels in Ghanaian foods. This study has had a great impact on the Health and Trade sectors of the economy. As a result of the findings, Rotary International carried out a sub-regional awareness campaign programme to sensitize people on the risks of consuming aflatoxin-contaminated foods. Between1999 and 2001, about 10 million people in Ghana, Togo and Benin were sensitized and are now aware of the dangers of aflatoxin-contaminated foods. The National Policy for aflatoxin control in food and feed has also been enacted in October 2022 through the effort of CSIR-STEPRI.
- Food Adulteration and contamination: The CSIR-FRI has generated data and information on the extent of Food Adulteration and contamination in the country. This information has been released to the Food and Drugs Authority (FDA) and is currently being used as a working document to alert staff of organizations responsible for checking food adulteration and contamination in the country.
- Alleviation of Iodine Deficiency Disorders in Ghana (IDD): CSIR was involved in the National Salt Iodation Programme, after a nationwide survey estimated that 33% of the then 110 Districts of Ghana had serious IDD problems. Traces of the problem were also detected in 67% of the remaining Districts. Today, iodated salt is consumed all over the country and the CSIR-FRI under its Salt Iodation Programme continues to train salt producers at the village level.
- Development and promotion of high protein-energy foods based solely on local cereals and legumes, with quality attributes comparable to the imported weaning foods. The Nutrition Unit of the Ministry of Health has helped to promote these formulations nation-wide to alleviate the prevailing malnutrition problems.[8]

SDG 3 & 12

Good health and Well-being & Responsible consumption and production **(Reduce child mortality. Cutting the under-five death rate by two-thirds)** The CSIR has developed technologies that can help eliminate malnutrition in the populace especially in children through:

- Sweet potato varieties rich in Vitamin A to support Vitamin A supplementary programme of the Ministry of Health
- Quality protein maize (QPM) varieties to support maternal and child health programmes of the Ministry of Health
- Cowpea varieties rich in iron to improve health of nursing and lactating mothers
- Salt iodation to improve the health of the general populace by preventing the incidence of goitre
- Development of high protein foods for infants to help the health sector to alleviate malnutrition in several communities
- Formulation of Recipes

SDG 4 & 6

Quality education & Clean water and sanitation **(Training and ensuring environmental stability. Cutting by half the proportion of people without sustainable access to safe drinking water and sanitation)**. Research and training by the CSIR have impacted positively on environmental stability through:

- Rehabilitation of about 230 ha of degraded forest reserves, mining sites and watersheds in 10 communities from Ashanti, Brono, Ahafo and Eastern Regions. This was done by inter-planting timber species with food crops. This initiative benefits the nation through clean air dry-out prevention, enhancing bio-habitat, nutrient improvement and increased stock of timber for foreign exchange.
- Technologies developed for seed preservation, improvement and seedling production with use of biotechnology. This will increase availability of planting stock for rapid reforestation and other agro-forestry interventions e.g. enrichment planting, modified taungya, genetically improved tree species and the current mixed plantations initiative.
- Technologies for wood processing developed for the efficient use of wood in the industry. There are increased recovery and high quality products to increase incomes to the industry and ultimately conserve scarce resources. An example is the local production of wood binder (glue) resins for the plywood sector at greatly reduced cost to save foreign exchange to the nation.
- Interventions that protect forest biology and health: A notable example is the ITTO Odum project in which technologies were developed to use forest resources to provide alternative livelihood for rural and sub-urban folks e.g. mushroom spawns, snail, grass cutter farming and bee-keeping. The snail farming technology was developed at CSIR-FORIG and today is being used all over Ghana through the agency of NGO's.
- Other initiatives involve comprehensive research into cultivation and use of bamboo and rattans (cane) as well as the use of coconut wood for furniture and other products.
- Other technologies developed by the CSIR to impact positively on environmental stability include:

  i. Soil erosion control to protect rural settlements and improve rural water system
  ii. Fabrication of agricultural waste recycling plant to recycle waste, which would have been a menace to the environment
  iii. Biogas plants that provide energy and help improve environmental sanitation
  iv. Hydrological surveys that have led to the siting of boreholes in rural communities

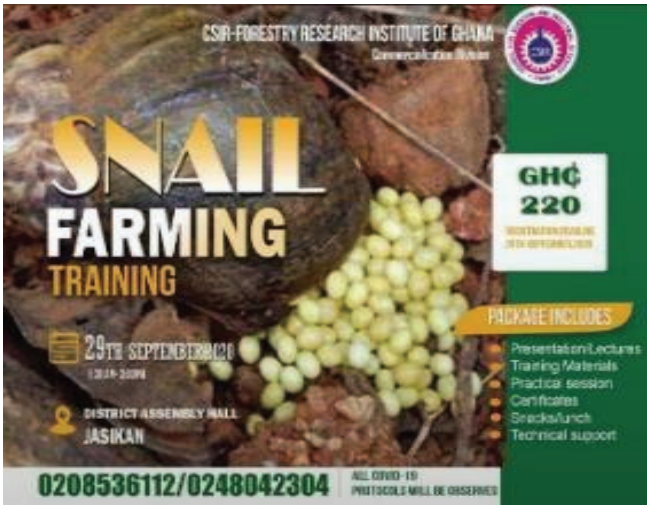
nationwide.

v. Small-scale irrigation systems driven by wind powered pumps drawing water from boreholes and hand-dug wells.
vi. A mechanized palm kernel shell separator, which replaces exiting traditional method of separation, which involves the use of clay sludge.
vii. Activated Carbon from Agricultural Waste. The range of raw materials, which can be processed in the equipment to form activated carbon, was extended to include palm-kernel shell. The project has been awarded two hundred million cedis (¢200m) by the Ghana Development Market place (GDM) to expand its pilot plant study.
viii. Production of alumino-silicate refractories from local materials to save at least $2.5 million annually in import substitution nationwide.
ix. Fabrication of integrated cassava processing plants in Central and Northern Regions saving foreign exchange of $2,000,000 in import substitution and creating of over 500 jobs in 3 Districts
x. Liquid soap from wastes of oil palm, coconut and cocoa husks.

4.3 Knowledge transfer and Skill sharing

The CSIR-TDTC has been instrumental in facilitating the transfer of knowledge and skills from the 13 CSIR institutes to the general public and industry through training workshops, seminars, mentoring and coaching of SMEs and online portals. CSIR-TDTC has been promoting the transfer and training of CSIR developed technologies via the social media with some positive results.

Some of the institutional flyers and posters promoted online by CSIR-TDTC are shown below:


CSIR-FORESTRY RESEARCH INSTITUTE OF GHANA
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Presentation/Lectures
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29TH SEPTEMBER2020
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ALL COVID-19
PROTOCOLS WILL BE OBSERVED


CSIR-FORIG
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FRIDAY
2ND OCTOBER,2020
SESSION ONE: 8:30AM -2:00PM
SATURDAY
3RD OCTOBER,2020
SESSION ONE: 8:30AM -2:00PM
SESSION TWO: 1:15PM - 5:30PM
0208536112
0248042304
CALL AND BOOK YOUR
PREFERRED SESSION NOW
CSIR-HEAD OFFICE
Opp. Former Chinese
Embassy, Agostinho Neto
Road
AIRPORT RES. AREA,
ACCRA
PACKAGE INCLUDES
Presentation/Lectures
Training Materials
Practical session
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CSIR-FORIG
BEEKEEPING FOR
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2ND OCTOBER,2020
1:15PM- 5:30PM
CSIR-HEAD OFFICE
Opp. Former Chinese
Embassy, Agostinho Neto
Road
AIRPORT RESIDENTIAL
AREA, ACCRA
PACKAGE INCLUDES
Presentation/Lectures
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Snacks/lunch
Technical support
GHS
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ALL COVID-19
PROTOCOLS WILL BE OBSERVED
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CSIR-FORIG
GET TRAINED IN
SNAIL
FARMING
THURSDAY
1ST OCTOBER,2020
CREDIT UNION TRAINING
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Training Materials
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HIGH LIGHTS OF CSR


KOSMOS
HIGH LIGHTS OF CSR


KOSMOS

4.4 Intellectual Property Co-creation between R-I-U

4.4.1. Introduction

The commercialization of technologies and innovations for industrial and societal development is a powerful mechanism to achieve impact. To meet this intent, the research institutions and the universities have to offer a suite of technologies and innovations from across their various institutions, for financial resource mobilization.

Technologies and innovations are transferred, typically via license agreements, to existing companies or to new ventures established for the purpose of commercializing the relevant technologies and innovations. The licensing stage would typically start with the institution conducting, amongst others:river has the potential to contribute to the betterment of both—the industry and academia.

- a due diligence on the interested company (financial, tax, legal and other matters);
- assessments of the business plan and sales projections;
- analyses of potential impacts (economic, social, environmental, etc.) from licensing the technology to an interested company; and
- a determination of the royalty rates and relevant license fees that would enable the institution to achieve a fair return on the investment.

Currently CSIR is making effort to have its developed technologies and innovations protected by patents, copyright, trademarks and other forms of intellectual property (IP) protection.

4.4.2. Developing a robust Intellectual Property Office in CSIR

The CSIR by its establishment and mandate will be more relevant and make greater impact in Ghana's socioeconomic and cultural development through technology development and innovation and the transfer of same for commercial interest.

The CSIR Intellectual Property policy is therefore, an essential first step in the operationalization of a formidable and sustainable technology development and dissemination strategy. Technologies and innovations are output of research. Research is expensive and a more sustainable Research financing approach within CSIR will be the commercialization of research output. An imperative for commercialization is to have a robust operationalization of the IP Policy of the CSIR which will ensure more consistent flow of resources from industry which incidentally accounts for over 60% of Gross Domestic Product (GDP) of most countries.

4.4.3. Prerequisite Structures

1. The IP Policy and IP Office

A decentralized and dedicated framework is necessary for the smooth operationalization. Decentralization maybe the first step in separating the key sectors of CSIR research area which include Agriculture, Environment and Health, Information, Engineering and Natural sciences. It affords the IP Offices to engage more closely with core researchers in their specialized areas which promotes efficiency. The office should be responsible for

orienting newly recruited staff and continuous awareness creation on the IP Policy of the CSIR, to mainstream IP rights and issues in CSIR's research mandate. A good appreciation of the benefits of IP rights shapes research output goals. For example, a scientist who invents a product or a process may hurriedly publish the findings in a Refereed Journal Paper or in a Conference Proceeding. This will deny the scientist and the Council the opportunity to file for Intellectual Property Right because the product or process may be deemed to be in the public domain which can be avoided with awareness created.

A dedicated staff and office with focus on IP issues alone allows for the separation of duties from the core duties of core research scientists, independent and impassionate assessments relating to IP applications and permits for the recruitment or training of Patent Attorneys with some proficiency background in the field of research who will conduct searches to establish novelty of the inventive step and draft IP related filing processes.

2. The CSIR-Technology Development and Transfer Centre (TDTC) and the CSIR Plus.

The CSIR IP Policy should be considered as a main driver in the development and dissemination of marketable technologies. Hence, vehicles like the CSIR-TDTC and CSIR Plus must play leading roles in the process of taking ownership and protecting the interest of CSIR from abuse. Thus, the CSIR-TDTC and the CSIR Plus should lead in terms of payment of the IP filing and renewal fees and negotiating for the licensing of same to commercial interests for revenue generation. They will then share the revenue accruing from IP Rights to the parties as spelt out in the IP Policy.

4.5 The CSIR and Innovation Market Value Chain Map (IMVCM) and the Innovation Trust Corridor (ITC)

The IMVCM has been developed as set of critical nodes in an innovation value chain with the potential to deliver successful commercialisation outcomes (figure 6). The Innovation Market Value Chain Map (IMVCM) enables researchers/innovators to achieve the following objectives:

- Identify and represent the research journey from idea to utilization stages
- Outline existing innovation market dynamics
- Identify the key stakeholders
- Identify the key economies/market players

The benefits of the ITC within the Commonwealth:

- Assures that innovations acquired are developed within the confines of safe and compliant jurisdictional laws and regulations
- Expands existing and new innovation markets where Trust, Safety, and Consumer Protection are implicit within a shared context
- Provides a platform for complementary and collaborative innovation development from an early stage by innovation parties.
- Assures Innovation can be obtained from legitimate, authentic and verifiable sources
- Assures superior technological advancement in the Innovation Trust Corridor
- Streamlining of IP Licensing in the Trust Corridor and the commonwealth of nations
- Guarantees Innovations factor, crosscutting global, cultural and other local nuances to manage the legitimate interest of Innovation parties
- Less developed IP markets would learn from

from advanced Innovation markets, ensuring that IP standards are raised with the Corridor.

• Equips the Corridor with potent and shared legislative tools to settle Innovation disputes across innovation jurisdiction [11]

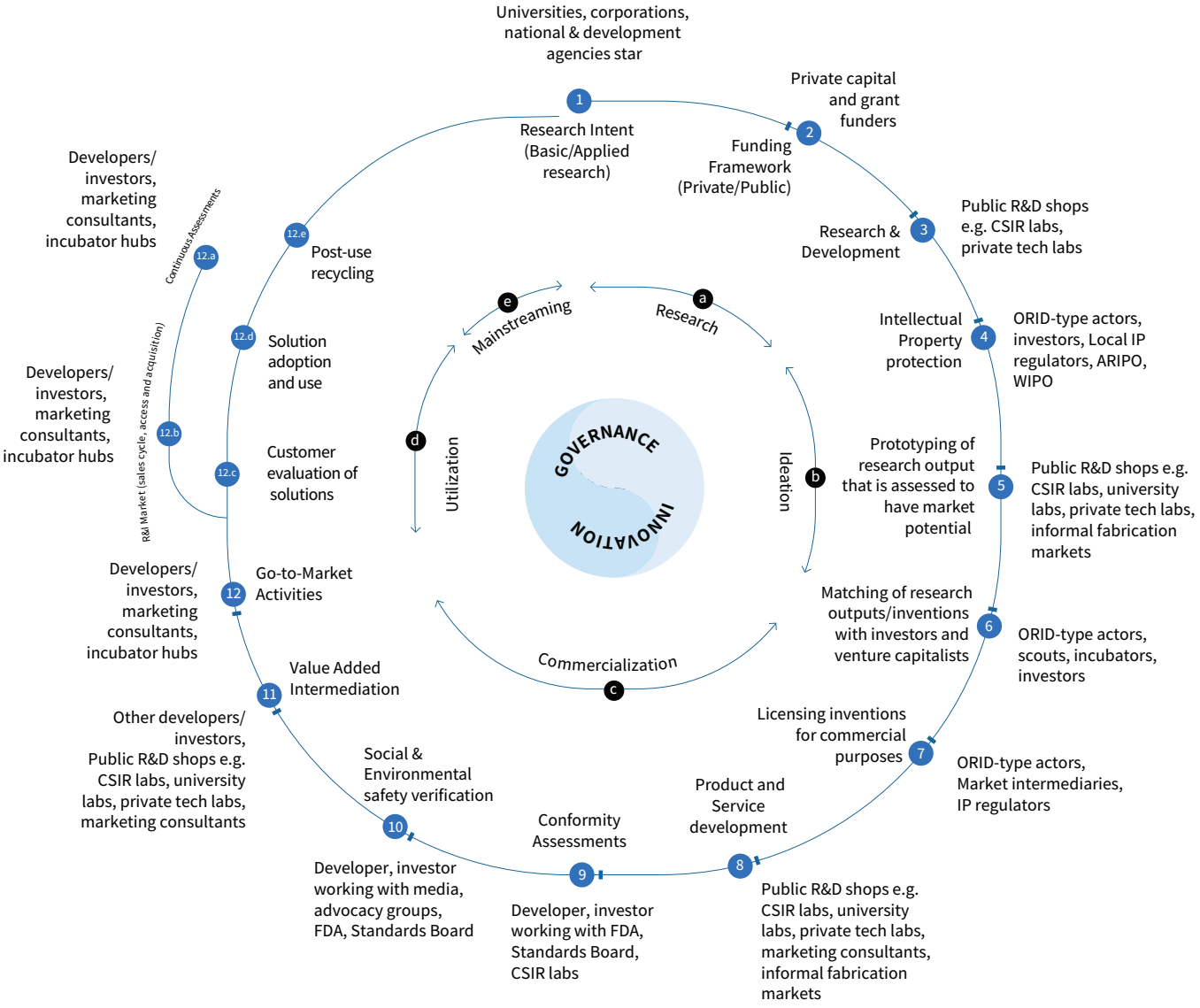


Fig. 6 The IMVCM Model (Courtesy Heritors Labs Ltd.)

The IP Office of the CSIR, the Commercialization Divisions of the CSIR Institutes must work in tandem with the CSIR-TDTC and the CSIR Plus. These bodies can serve as the main drivers in the development and dissemination of marketable technologies. They must play their respective leading roles to tap into the IMVCM processes and to ensure that commercialization does not become just local, but can take advantage of the Commonwealth science and research, innovation, resources, capacities, and infrastructure, as well as the market to thrive.

Chapter 5

Fostering Collaboration and Innovation Among Research Institutions, Industry and The Universities

5.1 Introduction

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.[12]

In 2022, the share of agriculture in Ghana's gross domestic product was 19.57 percent, industry contributed approximately 31.99 percent and the services sector contributed about 42.03 percent. The Agriculture in Ghana Market size is estimated at USD 3.40 billion in 2024, and is expected to reach USD 3.87 billion by 2029, growing at a CAGR of 2.65 percent during the forecast period (2024 - 2029). Varying estimates put the percentage of households owning or operating a farm at between 44.1 percent and 51.5 percent, amounting to approximately 7.3 million individuals. Ghana remains a major importer of food products, with imports of agricultural and related products estimated to have reached $2.6 billion in 2022. Food and agricultural imports Ghana remains a major importer of food products, with imports of agricultural and related products estimated to have reached $2.6 billion in 2022. Food and agricultural imports will continue to grow as Ghana's underdeveloped food processing sector is unable to meet increasing demand.[12]

Cocoa, oil palm, rubber and citrus constitute the major cash crops. The major starchy staples include maize, cassava, plantain, yam, cocoyam, rice, sorghum and millet and occupy a total land area of 3.40 Mha, representing about 43 percent of total cultivated land.

Livestock in Ghana contributed around 4.9 billion Ghanaian cedis (GHS), roughly 409.4 million U.S. dollars, to the country's GDP. This

represented nearly 13 percent of the contribution of agriculture to GDP in the country. [12]

5.2 Enhancing collaboration among the R-I-U

The Ghanaian research system mainly comprises research-performing organisations, intermediaries (three governing councils – Ministry of Education, Ministry of Health and Ministry of Environment, Science, Technology and Innovation) and government. The research-performing organisations include nine public universities, 13 institutes belonging to the CSIR, two teaching hospitals (Korle Bu Teaching Hospital [KBTH] and Komfo Anokye Teaching Hospital [KATH]) and three government-based research entities (Cocoa Research Institute of Ghana [CRIG], Centre for Scientific Research into Plant Medicine [CSRPM] and Ghana Atomic Energy Commission [GAEC]).

Research-performing institutions such as the CRIG, KATH, KBTH, KNUST, University of Ghana (UG) and the various institutes under the CSIR could be considered colonial legacy. This is because the nucleus of these research-performing institutions was established during the colonial period. These 'colonial' institutes have been instrumental in generating scientific knowledge and promoting the development of technology and innovation in Ghana. The CSIR and its institutes, for example, which evolved out of the then National Research Council, hold the biggest pool of scientists (about 450) in Ghana.[11] These institutions are still functioning, perhaps because of the model of colonial science pursued by the British. After Ghana weaned itself from the British in 1960, there have been very little additions (other than a few government agencies and public universities) to the existing research-performing institutions established during the colonial era. The existing ones have however been expanded and given more responsibilities. For example, KBTH, which was initially a general hospital providing health care, was expanded into a teaching hospital after the establishment of the University of Ghana Medical School (UGMS) in 1962. KBTH now houses training schools for various health professionals and offers a suitable ground for clinical training and research into health-related issues.[13]

The lack of new research-performing institutions to complement the colonial ones can be attributed to various factors, among which the ''lip service that Ghana has been paying to the role of science, technology and innovation, which is acknowledged but never made explicit''.[14]. For example, after government came up in 1995 with the Ghana Vision 2020 document (a blueprint for sustainable socio-economic development), placing emphasis on the need to create science and technology (S&T) culture at all levels of society, very little has been done to achieve the set objectives. A real attempt was the adoption of the country's first S&T policy in 2000 by the Ghanaian cabinet, but the working document on the management of the S&T policy, which followed in 2001, was never implemented.[15]
In fact, most of the policy measures on S&T had been implicit and scattered in many government documents until a second Science, Technology and Innovation (STI) policy was developed for the country in 2010. The main thrust of the STI policy is to ensure that S&T drives all sectors of the Ghanaian economy. The policy aims to promote basic research as the bedrock of scientific and technological innovation.

One of the major weaknesses of the national research system in Ghana is the lack of coordination resulting in duplication of efforts. The country's research system, like many others in sub-Saharan Africa, can be considered to be more of an ''assemblage'' than a ''system''. S&T initiatives in Ghana are implemented by a myriad of agencies without a single coordinating body responsible for S&T policy. The case of agriculture illustrates this point well. A review of the STI policy of Ghana revealed that agricultural research is largely sponsored by the CSIR, which falls under the Ministry of Environment, Science, Technology and Innovation (MESTI), while agriculture extension services and food safety issues are under the Ministry of Food and Agriculture (MoFA). In addition, the Ministry of Trade and Industry (MTI) supports agriculture processing programmes while the Ghana Cocoa Board (GCB) allocates funding for cocoa and shea nut research.[16]

The lack of adequate funds to support research is another major problem existing in the Ghanaian research system. Research and development (R&D) in the country is driven by a combination of core funding and project funding. Core funding takes the form of annual budgetary allocations, which are given to the MoE, MESTI and some other line ministries, which then release it to the research-performing institutions. However, core funding for research is limited. The funds usually go into paying the salaries of researchers and meeting some operational costs, with little left for actual research. For instance, in 2008, [80% of the CSIR's core funding went into salaries, which left about 20% for operations, including research. [16] Project funding therefore carries the cost of most research in Ghana.

The research-performing institutions and the universities, rely on grants from international donor agencies and philanthropists as a source of project funding. On the one hand, training of ''high-level scientific manpower'' is seen as emanating from enhanced ''collaboration between research institutions and universities''. Similarly, ''collaborations with developing and advanced economies'' is seen as having the potential to ''produce skilled personnel to drive a modern economy''; hence the need for such collaborations to be aligned with policies to ''minimize the brain drain''. On the other hand, the STI policy expresses a need to improve ''the quality and intensity of regional cooperation'', which is most likely what government had in mind by wanting ''to consolidate and widen bilateral and multilateral programmes''. All of the above means that, from a policy perspective, research collaboration in Ghana is seen as either directly or indirectly contributing to regional integration and a skilled Ghanaian scientific workforce. meaningful research. Most often, these external funds from donors for projects are short term in nature and thus the particular research activity ends when the project funding expires. Another source of project funding is the so-called 'internally generated funds', which refer to own revenue generated through the research-performing institutions. In the case of universities, for instance, the revenues are obtained from ICT fees, students' ID cards, health insurance and funds from accommodation facilities.[17]

Apart from budgetary allocations, the government of Ghana has over the years tried to find other ways of funding research in the country. In 2000, for instance, the Ghana Education Trust Fund (GETFund) was established to support educational

infrastructure development, including universities and polytechnics. Its central funding is based on a minimum of 2.5 percent of the prevailing rate of national value-added tax deductions. The national S&T Research Endowment Fund (STREFund) was also established by mid- 2008, with initial capital or seed money of approximately $500,000 to operate as an independent funding mechanism. In terms of gross domestic product (GDP), Ghana spent just about 0.38% of its GDP in 2010 on R&D. [18]

Having briefly discussed the research-performing institutions and sources of research funding in Ghana, together with the associated challenges, the focus will now shift back to the country's STI policy. Closer inspection of the few references to collaboration in the policy revealed that collaboration is valued for mainly two reasons, apart from the recognition that ''exchanges, partnerships, networking and cooperation have become the norm for keeping abreast of the pace of innovation in all sectors of the economy''. On the one hand, training of ''high-level scientific manpower'' is seen as emanating from enhanced ''collaboration between research institutions and universities''. Similarly, ''collaborations with developing and advanced economies'' is seen as having the potential to ''produce skilled personnel to drive a modern economy''; hence the need for such collaborations to be aligned with policies to ''minimize the brain drain''. On the other hand, the STI policy expresses a need to improve ''the quality and intensity of regional cooperation'', which is most likely what government had in mind by wanting ''to consolidate and widen bilateral and multilateral programmes''[13] . All of the above means that, from a policy perspective, research collaboration in Ghana is seen as either directly or indirectly contributing to regional integration and a skilled Ghanaian scientific workforce.

5.3 Developing a logical model for advancing R-I-U collaboration

Ghana in its pursuit of economic growth, experiences a great need for science, technology and innovation (STI) skills. Following the example of international counterparts, it is important that the Research institutions, Industries and Universities (R-I-U) enter into R-I-U agreements as a counter strategy to the growing skills need of the country (figure 7).

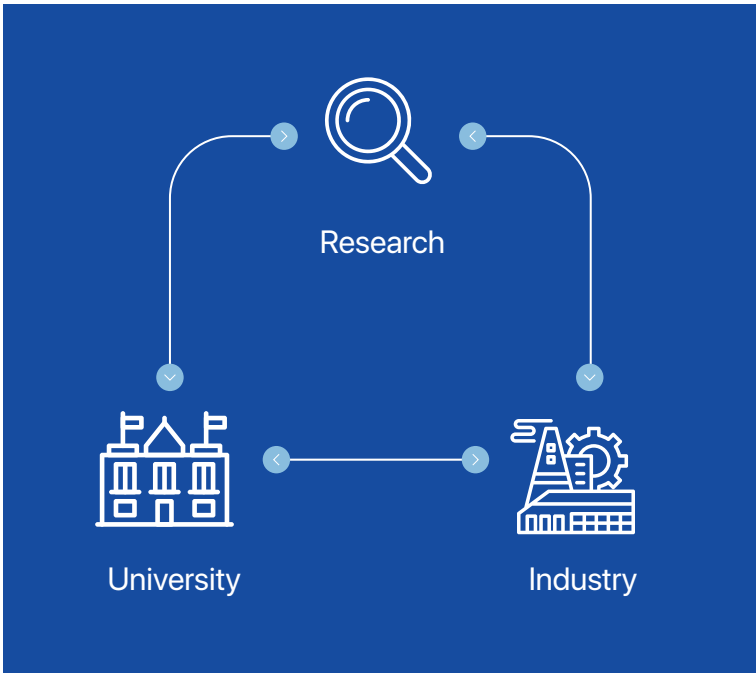


Fig. 7. The R-I-U structure

Education and training are central activities of a society, providing the main strategic thrust to the long-term development of a country. Educators, trainers and organisational developers face an unprecedented challenge designing curricula, policy and interventions to equip learners with life long learning skills for the

workplace which has become global, service oriented and knowledge based''. [19]

It is when technological progress in an existing technology cannot be made without a deeper understanding of the science underlying the technology and when new basic technologies need to be created from new science that R-I-U collaboration prove valuable. It follows that Ghanaian industry needs to co-operate with research institutions and universities for two major reasons:

- To facilitate the securing and training of STI personnel.
- To create new basic technologies from research for local industry.[19]

5.3.1. The Logical Model

In the R-I-U Collaboration framework, industry does not use research directly in its production of goods and services. Rather, industry utilises the technology that originates from research as well as the knowledge and skills gained. Through the partnership, universities can establish closer working relationships with the industry partners and gain access to resources necessary for research. In the case of short courses and post graduate degree programmes universities act as a steady source of qualified personnel.

According to a co operative research, R-I-U partnership strives to create a balance between:

- Technology pulled research and scientifically pushed research
- Short term and long-term research focus
- Proprietary and non-proprietary research information, and
- Vocationally relevant education and professionally skilled education.[20]

R-I-U partnership programmes can offer the creative tension needed to link technology and science in real time operation. Moreover, the R-I-U can serve to create progress in knowledge and by doing so develop the technological competitiveness of Ghana. ''Rapid technological progress and innovation (the only real basis of long-term competitiveness) are highly dependent on the individual's enthusiasm and freedom: A person cannot be instructed to be innovative, only to comply''. The R-I-U therefore strives to realise a management style that is contrary to top-down control, but rather one of supporting the accomplishment of things through people.

It is important to introduce the theory and concepts underlying the model for organising R-I-U collaboration. The concepts arise mainly from the fields of cybernetics and system thinking.

Cybernetics, the science of effective organisation, conceives management in terms of controlling complexity and aids an appreciation for what types of complexity reduction are likely to be effective. Cybernetics has proven to be a well developed, rigorous science that can be employed as a powerful management tool. Primary components of systems thinking include natural laws of systemic organisation (information control, interactions, interconnections); interpretative thinking (mental models, perceptions, and paradigms); and critical thinking (assumptions and presuppositions).

5.3.2. A Model for Organising an R-I-U Collaboration for Viability

The R-I-U as an organisation ***("any group of people working together to achieve a common and ongoing purpose which benefits people outside of their profession")*** first and utmost has to adopt a purpose which will dictate the aim and focus of the institution. A particular purpose implies some things about appropriate structures for the organisation. Most fundamentally, a purpose implies that the organisation needs parts that can-do identifiable parts of this purpose. These parts are referred to as the operational units that essentially realise the organisation's purpose (figure 8)

To illustrate, consider the purpose of an R-I-U Collaboration which includes:

- to promote a culture of excellence in science, engineering and technology
- to increase the pool of expertise to the industry
- to empower partnerships between higher education institutions.[19]

This three-part purpose implies that the organisation will need at least three subsidiaries to implement its purpose, for example:

- A skills development and training subsidiary to promote a culture of excellence in STI.
- A research subsidiary to increase the pool of expertise in the particular industry.
- A mentorship subsidiary to oversee the development of partnerships higher education institutions.

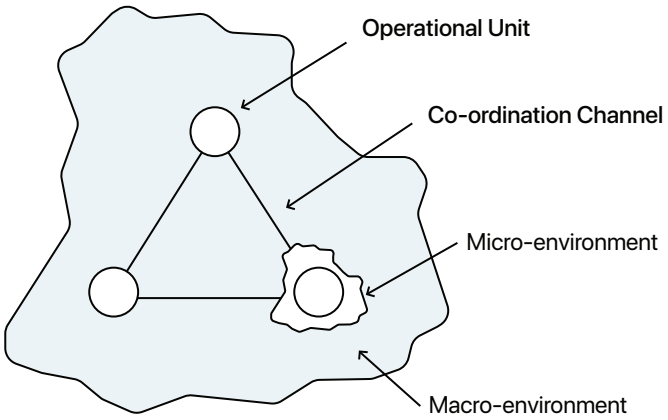


Fig. 8. Operational units realising the purpose of theR-I-U Collaboration

5.3.3. Management Control

In the R-I-U Collaboration, the management control ensures that the resources needed to function at the operational units are secured. This management function makes use of three channels (figure 9) to perform its duties: Co ordination, Monitoring and Control.

It is necessary to monitor and evaluate the outputs of the operational units to ensure that the operational units produce the output that the R-I-U Collaboration require and that it corresponds to what it was assigned to produce. In the context of limited resources, costs of failure are high. In research organisations, the selection and continuation of research programmes must be made on the basis of outstanding science and potential contribution to the organisation's mission.[19]

Evaluation should be performed at various levels of the R-I-U Collaboration. Examples of organisational levels in the R-I-U Collaboration are:

1. Each of the operational units of the IUPP, e.g. research unit, mentorship unit, training unit and so forth.
2. Operational elements acting within these units, e.g. elements of the research unit may be grouped according to focus areas: multimedia, broadband networks, radio access, et cetera.
3. Individuals performing the tasks at hand, e.g. students conducting research.

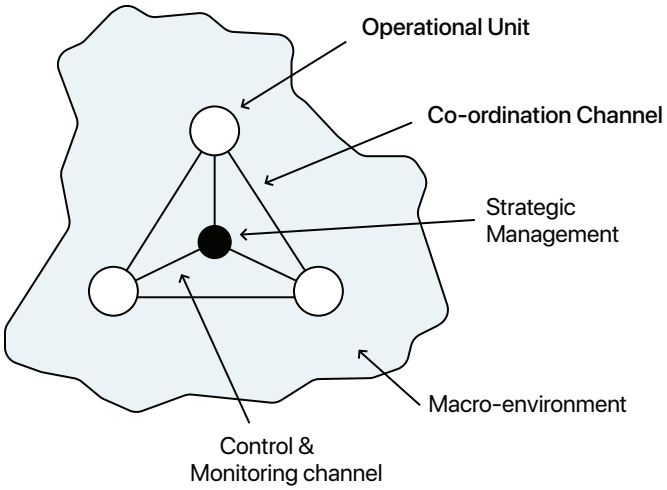


Fig. 9. Management control through three channels

An R-I-U Collaboration draws on the contributions of all the stakeholders for its success. These contributions do not just take the form of in kind and financial resources, but knowledge as well. The R-I-U Collaboration needs industry participation and involvement in the programme as a whole to tap its knowledge base. Industry involvement will clarify the skills need and an area where it is needed. More so, industry involvement will help to shape vocationally relevant education matching knowledge, skills and behaviour with the industry context.[19]

R-I-U collaboration programmes in Ghana should be encouraged. Furthermore, a model to organise these partnership programmes for viability can be a vehicle for progress in the future of science, technology and innovation.

5.4 Commercialization of research outcomes through a Research,Industry and University framework

5.4.1. Introduction

The CSIR, through its 13 research institutes, has had a long history of working with the private sector and other government institutions including the universities. The research activities of the Council translate into technologies designed to promote development in all sectors of the economy and enrich policy formulation and decisions.

The CSIR is positioned to work with both the private and the public sector to achieve food and energy security, environmental sustainability and economic development and ultimately contribute to the Ghana socio-economic development. Based on the expertise and resources at the various 13 research institutes, services the CSIR can provide to support the development include the:

- Supply of planting materials of improved crop varieties to promote local food production
- Supply of technologies to promote local poultry, livestock, fisheries and aquaculture production
- Supply of technologies to promote value addition through the processing of staple

food to reduce postharvest losses and promote export of value-added products
- Offer of analytical and technical services to industry to support manufacturing
- Use of local materials and other cost-effective technologies for the building and road construction industry
- Supply of technologies for afforestation, reforestation and restoration of degraded mine sites
- Offer of services in STI policies formulation for development

5.4.2 Specific Contributions of the CSIR to the R-I-U Ecosystem

5.4.2.1 Agriculture

Situational Analysis of the Agricultural Sector

The Ghanaian economy has grown at an average annual rate of 4.8% over the past three decades. This has led to a drop in the poverty rate, by 8.6% in urban areas and by 10.4% in rural areas during the last decade. Although there has been a substantial overall decline in the incidence of poverty in Ghana, poverty still has a firm grip especially in the savannah regions of the north (Northern, Upper East and Upper West regions), where chronic food insecurity is widespread and livelihoods are more vulnerable. The people living in these regions have limited access to basic social services, safe water, roads, that are accessible year-round, and electricity and telephone services. Poverty is most severe among food crop farmers, who are mainly traditional small-scale producers.[20]

The agricultural sector is a key component of Ghana's economic activity. Its share of Gross Domestic Product (GDP) has decreased slightly in the last decade to about 8.9%. Nonetheless agriculture is still a major component of the economy, generating a value of close to US$6bn. Two-thirds of agricultural production comes from food crops and livestock. Agriculture is not only a main contributor to Ghana's GDP; it is also the biggest sector in terms of job creation. Despite a decreasing trend, agriculture still provides over 56% of employment, in farming and herding.[21]

While Ghana's overall real GDP enjoyed annual growth rates around 6% from 2000 to 2008, the agricultural component of GDP has been growing at a lower average rate around 4.4% per annum. With population growth of more than 2% per year and an increase in per capita consumption, Ghana faces an ever-increasing domestic demand for food crops and livestock. Ghana is currently not food self-sufficient. For example, the self-sufficiency rate for rice is particularly low with only 30% of domestic demand met locally. Rice imports rose to more than 500,000 tons (with an estimated additional 100,000+ tons imported illegally) in 2008 and accounted for about 3% of all import expenses or roughly US$ 230m.[21] This not only puts pressure on Ghana's trade balance, but also makes Ghana vulnerable to global price increases and supply shortages. There are various ways by which the CSIR can contribute to increased food production through the research capacities of its agriculture-based institutes. These institutes have capacities reflected in their respective mandates.

The CSIR-Savanna Agriculture Research Institute (CSIR-SARI) has the capacity to develop appropriate cropping systems, varieties of crops such as maize, rice, sorghum, millet, soybean, cowpea, groundnuts, bambara

groundnuts, cotton, and vegetable crop. The Institute provides appropriate plant protection and post-harvest systems, and introduces soil fertility improvement measures, which are adapted to the needs of farmers in the different ecologies of northern Ghana.

The CSIR-Crops Research Institute (CSIR-CRI) conducts research to develop improved varieties of food and industrial crops and their production technologies to enhance food security and poverty reduction. The relevant crops include: Legumes (cowpea, Soya bean, groundnut, canning beans, and bambara groundnut), Cereals (maize and rice), Roots and Tubers (yam, cocoyam, cassava, taro and sweet potatoes), Vegetables (pepper, garden eggs, tomato, onion, and leafy vegetables), Tropical Fruits (citrus, mango, avocado, cashew, pineapple, and pawpaw), and Industrial Crops (rubber and sugarcane). The CSIR-CRI has over the years developed and disseminated through the Ministry of Food and Agriculture demand-driven technologies to build capacity for sustainable food and industrial crop productivity.

The CSIR-Animal Research Institute (CSIR-ARI) has the overall mission to develop and transfer technologies to promote sustainable animal agriculture; improve livestock production and productivity to reduce poverty and enhance commercial production; enhance natural resource management. The Institute also provides advisory services to small, medium-and large-scale farmers in Ghana and offers advice to Government on policies in the animal industry in Ghana.

The CSIR-Soil Research Institute (CSIR-SRI) has the capacity to undertake scientific research to generate information and technologies for effective planning, utilization and management of the soil resources of Ghana for sustainable agriculture, industry and environment.

The CSIR-Oil Palm Research Institute (CSIR-OPRI) has the capacity to research into oil palm and coconut which under the current CSIR thematic areas are classified under food security crops. Oil palm and coconut have huge potential to contribute to the socio-economic development of the country if given the needed attention. The CSIR-OPRI on its part, through sustainable and demand-driven research over the years, has developed several technologies and generated relevant scientific information for the support and development of the oil palm and coconut industries in Ghana.

The CSIR-Plant Genetic Resources Research Institute (CSIR-PGRRI) collects, characterizes, evaluates, documents, conserves, distributes and promotes the utilization of the plant genetic resources of Ghana to forestall their extinction.

Priority Areas for Agricultural Development

(a) Seeds: Creation of high yielding and drought-resistant seeds of varieties of crops

Seeds and other planting materials remain perhaps the most essential ingredient for sustainable crop food production. The CSIR through the work of its agricultural research institutes has released for cultivation numerous improved varieties of seeds which are currently supporting ongoing programs such as the Planting for Food and Jobs. (See Appendix III).

The CSIR has the capacity to supply all certified seeds and other planting materials required for the mass production of staple food to make the

mass production of staple food to make the country food secure.

It is instructive to note that some of these high yielding crop varieties developed by the CSIR-CRI, are also climate smart, early maturing and drought tolerant (e.g. the maize, rice, sorghum, soybean and cowpea varieties), early bulking and well adapted cassava varieties, and bio-fortified (beta-carotene and anthocyanin rich) sweet potato varieties. Some crop varieties developed by the CSIR-CRI, which are adapted for industrial use are:

- Sorghum - Guinness Ghana Brewery Limited
- Rice, maize and pearl millet - Nestle Ghana
- Soybean and Groundnut – Oil and Poultry feed industries
- Cassava – Industrial starch and breweries (Root beer)

(b) Fish Production

The Government of Ghana has launched the *"Planting for Food and Jobs"* initiative with the aim of increasing food sufficiency, reducing food imports and creating jobs for the youth. In terms of fishery and aquaculture, the country imports more than US$400 Million worth of fish per year. There is a huge potential for local production to meet local consumption. The CSIR-Water Research Institute (CSIR-WRI) has over the years increased local fish production through participatory research and technology transfer in aquaculture, and sustainable management strategies in inland and immediate coastal waters of Ghana. This achievement finds expression in the following activities:

i. Breeding and selection of the Akosombo strain of the Nile Tilapia (Oreochromis niloticus) at CSIR-WRI ARDEC, Akosombo.

- The technology has shown great potential to contribute significantly to fish farming in Ghana.
- The technique ensures selective breeding of locally available stocks and release brood stock of the genetically enhanced strain to local fish farmers for culture.
- Currently, the breed continues to attract the attention of fish farmers and hatchery

- in the country and within the West African sub-region.
- The breed grows about 30% faster under cage culture condition or system than those in the wild and has a higher survival rate
- It helps alleviate poverty and make more animal protein available to Ghanaians at a cheaper cost, with less input imports.
- Provision of adequate numbers of fingerlings for aquaculture farms in Ghana and for export to other countries especially in the West African

ii. Assessment and provision of services for establishment of fish farms.
iii. Training of fish farmers in sustainable aquaculture production for increased local production and export market

(c) Improved Poultry and Livestock Breeds

Ghana currently has a shortfall in meat production as domestic production is estimated to reach 35,000 tons by 2017 was to supply less than 25% of demand. Meat imports were therefore expected to increase from 14,000 tons to 158,000 tons.[22]

The improved poultry and sheep breeds developed by the CSIR-Animal Research Institute (CSIR-ARI) are aimed at reducing high importation of day-old chicks in poultry production and meat, consequently contributing to job creation as well as increasing Ghana's foreign exchange reserve.

(d) Livestock feed production technologies

Compounded feed cost for livestock production is very high. Additionally, forages for livestock feeding are scarce especially in the dry seasons.

The CSIR-ARI has technologies for livestock feed production such as:

- The use of agro-industrial by-product to reduce the cost of feed in pigs production;
- Pelletized feed for grasscutter and other small ruminant production which ensures sustainable supply of feed; particularly during
- the dry season; and also reduce high labor cost of cutting grass;
- the production of highly nutritious, productive and quality forage (cereals and legumes), hay, silage and multi-nutrient feed block.
- These technologies also have the added advantage of contributing to the reduction of communal conflicts between crop and livestock farmers in areas like the Afram Plains.

(e) Value Addition to Livestock Products

Value addition to livestock product is relatively low. Thus, actors in the livestock value chain are not competitive and do not make the needed returns on their investments. The

CSIR-ARI has technologies for value addition to milk (e.g. yoghurt production), and a high quality meat product (e.g. smoked meat products to feed the meat and dairy processing industries to create jobs for the women and youth. The Institute also has solar drying technologies for hygienic and tar-free meat and fish products. CSIR-ARI's improved hot-wood smoker and solar drying technologies have reduced the energy cost in meat processing and the shelf life of meat products as well as carcinogenic effects of traditional smoking thereby enhancing their export value.

(f) Improved Livestock Production Technologies

In spite of the profit in pig production a lot of farmers do not go into its production because of the waste management problems. The IMO technology developed by the CSIR-ARI has helped to eliminate the stench associated with pig production making it possible for pigs to be raised in urban communities. The technology has reduced labor cost in pig production.

In terms of job creation, the use of CSIR-ARI technologies related to improved breeds, cost-saving feed packages and environmentally friendly technologies make livestock production more competitive and lucrative. This has the potential to attract the youth and other investors into the livestock agribusiness.

(g) Non-timber Forest Products

Mushroom Production

CSIR-Forestry Research Institute of Ghana (CSIR-FORIG) and CSIR-Food Research Institute (CSIR-FRI) have developed technologies in oyster and oil palm mushroom production. Mushrooms are well known and form a major part of the diet of both rural and urban communities in several countries. Research has been conducted to maximize production of both exotic and indigenous edible mushrooms using appropriate substrate from agro-forestry wastes. Currently the improved methods of cultivating the oyster and oil palm mushrooms have been transferred through training programs to some communities in southern Ghana. Mushrooms are being cultivated within the Accra and Kumasi metropolis where the technology has been widely adopted. With the recent policy on the country's one district one factory agenda by the Government to promote the economic welfare and livelihoods of the urban poor and rural communities, there is the need to widen the dissemination of the mushroom technology to other parts of Ghana. Local communities will be trained in procedures for oyster and oil palm mushroom cultivation. Currently these mushroom types are selling at retail prices of 40-50 cedis a kg and wholesale prices of 24-30 cedis a kg. In a 100 square foot growing area, growers are averaging around 2400 harvested kg per year, with six growing cycles, or about one harvest every eight weeks. This is clearly a lucrative venture for rural and urban communities. The potential for canning these products for long term preservation and or export is high.

Snail Production

Snails are rich in protein, low in fat and cholesterol, which make them a highly preferred choice of meat for many people in Ghana. It is estimated that more than 80% of the rural population in Ghana depends on bush meat for their animal protein, and snail constitute approximately 10% of the consumption and

trade in bush meat. Since snails are seasonal creatures, the only way to ensure sustainable all-year round supply is through rearing/farming. Interest in rearing of snails and production of snail meat for domestic consumption and/or for sale has increased considerably in recent years, and the technology for doing so is well developed.

Ghana exports at least 1700 kilograms of snails to countries such as the Netherlands and the United States. Snail farming in Ghana has become such a lucrative business that the CSIR-FORIG can offer professional advice to prospective farmers to enable them to harvest more yield for the local and international markets. Snail farming is simple and relatively easy to undertake. It does not require large capital inputs to start and maintain, compared to other livestock farming ventures. Snail farming is easily integrated into a diversified farming venture, such as cocoa, oil palm or tree plantation projects. However, it can also be developed as a standalone enterprise whether small, medium or large scale
for high profitability. CSIR-FORIG is experienced and very well positioned to provide the needed technical and managerial support towards the development of a vibrant snail farming enterprise in Ghana, including the possibility of a factory scale business venture under the one district once factory policy. This could be done through the setting up of small to medium scale snail farms that can produce between 50,000 to 100,000 snails per year. At least ten farmers in each community in a district could be targeted and engaged and supported as snail farmers. By thus significantly considerable number of local people bill be gainfully employed.

(h) Irrigation

The CSIR through its Water Research Institute offers the following services to boost agricultural production:

i. Assessment and provision of services for groundwater sources for
ii. irrigation/agriculture.
    Assessment and provision of services for the establishment of dams and dug-outs for irrigation/agriculture (Government's One
iii. Village, One Dam Policy)
    Application of ICT technologies to improve water management on farms for increased rice and vegetables production and consequent decreased food import bills.

Harvesting of water for agriculture. The CSIR-SRI has the capacity to identify suitable locations for reservoir constructions, drainage channels, to harvest flood water for agricultural use. In addition the use of simple water harvesting techniques such as hand dug wells, dykes, ponds etc. to support small holder irrigation.

(i) Soil Fertility Improvement

The CSIR has provided and promoted integrated soil fertility management technologies for all crops including cocoa for climate smart agriculture. Soil fertility is the number one constraint to crop production in Ghana currently and through the adoption of improved technologies that are available at the CSIR-SRI, there will be increased crop production, increased yields by over 100% from current levels, enhanced food security and reduced hunger in the country. Inorganic fertilizer use efficiency could be improved by 50-60% making investment in inorganic fertilizer a worthwhile investment. Additionally employment opportunities could be created along the ISFM-crop/animal production value chain. Additionally, the CSIR-SRI has provided and promoted intermediate mechanical technologies to enhance efficient and timely land preparation for sustainable crop production and increased agricultural productivity. This would also include the promotion of conservation agricultural practices such as minimum tillage, cover cropping and crop rotation.

Nutrient and Water Management

The CSIR has technology to make Ghana self-sufficient in rice production through the promotion and adoption of sustainable soil, nutrient and water management protocols in the inland valley and flood plains of Ghana termed the "Sawah" technology. Promoting and upscaling the "sawah" technology countrywide to enhance and increase local rice production in order to reduce rice imports. The "sawah" technology is a simple and easy to adopt, resource-poor farmer friendly and environmentally friendly technology that has the potential to transform rice production in this country and turn her into a net rice exporter. This technology has increased rice yield from less than 2 tons per hectare under local system to about 8 tons per hectare currently. When only 30-40% of lowlands in Ghana are put under "sawah", local rice production can increase to over 100% of the country's requirements. Over US$400 may be saved from annual rice imports and millions of jobs created through youth rural employment.

Land Suitability Information

The CSIR has provided detailed information on the potentials (site specific productivity status) of all soils across the country for crop and animal production. This will provide a decision support tools and reliable soil information for agro-based investors, farmers and other land users. The existing CSIR-SRI digital database could be upgraded to provide an online service for effective and sustainable soil management practices for all categories of crop (cereals, legumes, roots/tubers. vegetables, plantation crops etc.) for farmers across the country. Farmers would have access to credible soil information through the use of mobile Apps. Quality soil information is very necessary in modernizing Ghana's agriculture. With the necessary resources and logistics support from Government, the CSIR-SRI will acquire mobile

soil testing vans to provide on-the-spot soil testing and advisory services to farmers.

(j) Post-Harvest Storage

Technologies for postharvest storage to reduce postharvest losses and introduce competitiveness in local food production are available at the CSIR. These technologies are being transferred to farmers through the Ministry of Food and Agriculture. (See Appendix III)

5.4.2.2 The Environment

Situational Analysis of Ghana's Natural Resources

Ghana is rich in terms of biodiversity. In Ghana, about 15% of the population depends on biodiversity for their livelihoods (3.6 million people out of 20m people in 2012) This figure is expected to increase in 2018. The benefits of plants, animals, water resources and microbial biodiversity to the people of Ghana are enormous. These range from economic (source of rural and urban income, export earnings), social (as sources of food and food security, biofuel, medicine for health maintenance and cure of diseases and ailments), religious and cultural (avenue for spiritual inspiration), aesthetic and recreational to ecological (watershed and catchment area protection, wind/storm break, forest regeneration, soil fertility maintenance, etc.) and environmental (maintenance of atmospheric carbon levels and absorption of pollutants, etc.). Unfortunately, biodiversity is being lost due to the destruction of forests.

Ghana loses about 2 % of it forest cover annually representing a loss of 135,000 hectares per year. Cumulatively, the country has lost half of her forest cover as at year 2000, and data indicate that only 4.6 million hectares of closed forests remained in 2011 with 1.6 million hectares being forest reserves. In 2016, the World Bank reported that 119 Plant species (higher), were threatened in Ghana according to its collection of development indicators, compiled from officially recognized sources.[23]

The major direct causes of deforestation cited were agricultural expansion (particularly for cocoa and other cash crops); unsustainable harvesting of wood for firewood and charcoal production; illegal logging; uncontrolled wildfires; population and infrastructure development pressures; and mining and mineral exploitation.[23]

But Ghana's socio-economic development has to harness resources and income from all sectors of the Ghanaian economy including the forestry sector. It will be successful if Ghana is able to generate income from the forests, reduce wood imports, maintain our water bodies and regulate climate. Consequently, it is important to apply technologies that have been developed by CSIR-FORIG to help in the rehabilitation of degraded forests and mined sites and in the process create jobs and opportunities for local communities and subsequently contribute towards addressing the food security situation in Ghana.

The CSIR-FORIG has the capacity to enhance the sustainable management, conservation and efficient utilization of Ghana's forest resources. It has research centres at Bobiri and Amantia both in the Moist, Semi-Deciduous Forest Zone, Benso in the Wet Evergreen Zone, and Bolgatanga in the Savannah Zone.

There are also research stations at Subri, Afram Headwaters, Pra-Anum, Accra plains, Northern grassland, Bia Tano and Asenanyo. All these centers are already working in strong collaboration with local communities.

The CSIR-WRI generates and provides scientific information, strategies and services toward the rational development, utilization and management of the water resources of Ghana. This is to support the socio-economic development of the country, especially in the fisheries and agriculture health, industry, energy, transportation, education and tourism sectors.
The CSIR institutes led by FORIG, WRI and SRI have technologies for the rehabilitation of degraded mine sites (polluted soils/water) into arable and productive lands for crop production and also enhance environmental conservation. In addition, degraded agricultural lands due to the adoption of poor conservation practices would also be turned into productive lands. The institutes have technologies (e.g. land remediation/reclamation, revegetation, evergreen agriculture, agroforestry, stone bunding, tied ridges etc.) that can be used to restore such unproductive lands for agriculture and forestry. Polluted soils and water resources due to "galamsey" can be reclaimed and restored to normal conditions for crop production and domestic use.

Afforestation/Reforestation and Rehabilitation

The CSIR-FORIG has a national tree seed centre, that can test for seed quality, store at optimum conditions and preserve forest seeds for future use. Seeds produced can also be exported to earn the country foreign exchange.

Additionally, the CSIR-FORIG has developed seedling technologies and can produce at least one million seedlings annually. The Institute undertakes training of communities to raise tree species including economic and socioeconomic species such as Triplochiton scleroxylon, Entandrophragma cylindricum, Celtis spp, Aningeria spp, Khaya anthotheca, Nauclea diderrchii, Albizia ferruginea and parkia. These seedlings are produced to support community and national activities. Undertaking this training are hugely profitable and sustainable as it has been securing at least 1 million jobs for the local communities. Community members also get income (one million cedis annually) from at least one million tree seedlings produced annually. Promoting nursery technologies and plantation activities have led to other social and environmental benefits that are hugely important for Ghana's socio-economic development achievements and sustainability. Appendix IV. The intrinsic and monetary value of these benefits cannot be emphasized enough.

(b) Water Resources Management

The urban and rural water supply coverages in Ghana are 70 % and 62 %, respectively. The Government of Ghana has pledged to achieve a national coverage of 100 % by 2025. This, invariably, would demand huge investments in the water supply. Also, to complement Government efforts, reliable information and data on the occurrence and sustainable management of the groundwater resources of the country would be required and the CSIR-Water Research Institute is positioned to make resourceful contribution in this effort.

Improved borehole siting techniques using 2D/3D resistivity technique has the potential to assist in the quest of Government of Ghana's agenda to secure every citizenry access to

in the quest of Government of Ghana's agenda to secure every citizenry access to sustainable water supply. The introduction of 2-D/3-D LUND resistivity equipment by CSIR-WRI in 2006 highly improved the drilling success rate from 30 % to 100 %.

For the industrial sector, evidence on the ground suggests that Government's "One District, One Factory" project is encouraging investment across the length and breadth of Ghana, a positive sign of the beginnings of value addition to the country's resources to move the economy from one reliant on production and export of raw material to a value-added industrialized economy. Undoubtedly, government is creating the enabling environment for the private sector to thrive. The CSIR-WRI will make contributions in the following respects:

- Assessment and provision of services for surface and groundwater sources for mines/factories/industries/companies.
- Providing laboratory services to sachet and bottled water companies to ensure potable water quality for increased exports of products.
- Providing laboratory services/monitoring and sustainable management of industrial wastewater at manufacturing and mining companies, thus decreasing the dependence of such companies on foreign service providers in this area.

Several studies have shown that Arsenic (As) and Manganese (Mn) concentrations in water bodies in mining areas are above guideline values for drinking, suggesting that human health risk is a great concern for As and Mn. Groundwater from mining areas shows high levels of As, Lead (Pb) and some Uranium (U). The Institute's expertise and laboratories are available for the sustainable management of our water resources in a holistic manner in order to bridge the gap between supply and demand in Ghana.

5.4.2.3 Industry

(a) Agro processing industry

The CSIR-FRI has the capacity to conduct applied market oriented research into problems of food processing and preservation, food safety, storage, marketing, distribution and utilization, and national food and nutrition security in support of the food industry and also to advise government on its food policy. The CSIR-FRI continues to contribute to the socio-economic development of the country through the areas of poverty alleviation, post-harvest losses and most importantly, food security.

Specifically, CSIR-FRI:

1. Provides appropriate technology packages for processing and storage of raw agricultural produce to facilitate curtailment of post-harvest losses to ensure food availability and sustainability for the country.
2. Promotes value addition to raw agricultural commodities to obtain various product profiles, and ensures shelf stable products for local and export markets.
3. Improves nutrition using appropriate technologies to formulate food products that meet nutritional needs and standards status of vulnerable groups.

Some of the Institute's technologies that can contribute to the socio-economic development are found in Appendix IV.

(b) The Wood Processing Industry

CSIR-FORIG has a modern state-of-the-art Wood and Furniture Testing Centre (WFTC). With experts ranging from wood scientists / wood technologists to civil/wood engineers, WFTC has the expertise and experience in testing wood and wood products for the country. With proper legislation, the Centre can ensure that inferior furniture products coming into country can be minimized. Apart from ensuring that imports of furniture into the country are of a high quality, it will also help in reshaping the production of local furniture by equipping local artisans with the skills to manufacture high quality products. The Centre will thus support the wood industry through testing services, research into efficient utilization of wood species, products development and their standardization.

The Centre is currently going through the necessary procedures to get accredited under ISO/IEC 17025. The scope of tests and services include testing of furniture (chairs, tables, beds, drawers etc.) of all types (plastics, wood, metal, swivel, upholstery, composites, etc.), wood and wood-based materials such as plywood. The Centre is collaborating with the Ghana Standards Authority (GSA) to ensure that high quality wood products that meet international standards are certified to be in the market, for durability and consumers' safety. If the wood testing lab is legislatively supported by the Government, it will help the local industry to create jobs and be internationally competitive. It is estimated that not less than I million cedis will be added to government revenue from paid tax on tested imported and locally manufactured wood products.

(c) Extractives for the Cosmetic, Medicinal and Wood Industry

The CSIR-FORIG has conducted research into the chemical composition of wood, concentrating on the chemical characteristics of Ghanaian woods and other vegetable extracts that can be used in the wood industry. Research has concentrated on the extraction of tannins to produce adhesives, essential oils

from different species to form the basis of the cosmetic industry and the extraction of prekese syrup from the prekese fruit.

The Institute also concentrated on using cassava starch as a plywood extender in the plywood industry. The technology has proven to be useful.

Economic Benefits to Nation

- Currently total adhesive mix is 20% Cassava Flour and 80% Wheat Flour
- Contribution of Cassava Flour Adhesive alone to Plywood Industry amounts to about $900,000 per annum.

The promotion of this technology can expand the agricultural sector in terms of jobs and increased income for local people. It could also cut down significantly the cost of importation of industrial glue for the plywood sector. With respect to Ghana's socio-economic development, there is the need to establish a factory to manufacture the flour on a commercial scale. This in turn will feed into the one-district-one-factory program.

(d) Promotion of Lesser Used Timber Species

The country must expand its use of lesser known/lesser used species of timber. Properties of over 35 Lesser Used Species (LUS), which have proved to be good substitutes to the dwindling traditional species, have been established. High value species which are currently threatened such as Odum, Dahoma, Essia have been substituted by Awiemfosamina, Bonsamdua and Pampena, hitherto uncommon on the Ghanaian market.

Economic Benefits to Nation

Total annual volume of timber is 800,000 m3. Within the last 5 years about 10% of LUS have come on the market contributing about $24 million per annum to the wood industry (with a total export value of $200 million) and another estimated value of $15 million to the domestic market.

5.4.2.4. Advanced Precision Machining Center: Model Foundry and Engineering Fabrication

Industrial creation and expansion require machining parts of equipment and research support into products. The skill in fabricating and producing machine parts is the foundation for industrial development. Presently, to set up most factories in Ghana requires the setting up of subsidiary companies or simple import machine parts to feed the main factory. This is partly due to lack of facilities to produce advanced precision machine parts in the country. Tools available for factories and artisans are largely rudimentary and knowledge base in the material selection is weak. Factories therefore experience drawbacks, reduced throughput as a result of inefficient equipment due to lack of high precision machine parts.

To support industries in product development and fabrication of machine parts, CSIR-Institute of Industrial Research (CSIR-IIR) has an established machine workshop with the capacity to produce various machine parts to provide industries with machining parts for a wide variability in specific turning operations for agriculture, gas, oil and water industries etc.

In terms of benefits, the potential for scale-up and production of machine parts and voulumes

exist. The establishment of an Advance Precision Machining Support workshop in CSIR-IIR, able to be replicated across the Regional and District Capitals in Ghana will support manufacturing sector of the economy. Each Regional workshop will be equipped to produce standardized machine and equipment parts to support the artisanal equipment fabricators in Ghana. The following are the machines that will be needed (minimum) for each advance precision machine workshop:

- Computer Numerical Controlled Lathe (1X)
- Welding Machines (2X)
- 3D Printing Equipment (2X)

5.4.2.5. Industrial Skills Development

According to a World Bank report, relative weaknesses in technology and innovation coupled with labour market inefficiencies have adversely affected the competitiveness of local industries in Ghana on the local and global scenes. In spite of its transition from a low income to a low level middle income status, Ghana still faces a competitive challenge. According to the study, this lack of competitiveness seems to stem from poor productivity aggravated by limited supply of equitable and quality training opportunities to match the needs of the rapidly growing youth population and the demands of the growing industrial sector.

Solar Energy Skills Development Center

Although the benefits of sustainable energy technologies such as solar energy use are fully acknowledged, the current problems emanating from lack of research and specific training drives low consumer confidence in sustainable energy technologies. There is a clear demand for solar PV systems, for example, as an alternative to unreliable hydro-power. However, consumers are hesitant to make the investment over concern of on-going lack of technological support. Greater deployment of solar systems in Ghana would require an increased need for qualified personnel with thorough knowledge of installation, maintenance and trouble shooting skills. The proposed project is directly related to Ghana Government's remit to conduct research and develop modern renewable energy technologies to help educate electrical and electronic engineers and provide them with higher level technical knowledge in renewable energy systems.

The CSIR-IIR has received support from Skills Development Fund (SDF) to train over 1400 members of Certified Electrical Wiring Professionals Association of Ghana (CEWPAG) on how to install and maintain solar PV systems. The Institute is establishing a National Sustainable Energy Research and Training Centre. The Centre will include an Electrical wiring center to collaborate with partners in an interdisciplinary team to develop renewable energy systems and to establish link between sustainable energy use and development in Ghana. It is hoped that the technical training to support industries will then help boost capacity development in solar systems design and help spur solar uptake. The CSIR-IIR is looking at a partnership with AGI to set up an industrial training Centre to support industry in several areas such as plumbing, welding etc.

5.4.2.6. Metrology/Instrumentation

Calibration and repairs of scientific equipment in the Ghanaian industry is a major drawback to

Ghana's export industry. This leads to price discrepancies for example leading to low consumer confidence in the pricing of commodities in Ghana. The Metrology Unit of CSIR-IIR has a calibration laboratory with ISO 17025: 2017 (Accreditations in Mass and Temperature Measurements) and Scientific Equipment Repairs Division. Recently through the TRAQUE project, the Institute has added new capabilities to provide new services in the calibration of:

- Temperature
- Mass
- Electricity
- Pressure and
- Acoustics

The CSIR-IIR therefore has the mandate to provide services in the calibration and repair of scientific equipment and instrumentation.
The Institute can provide services in the following industries:

- Process Industries
- Research Institutions
- Hospitals and Medical Laboratories
- Secondary and Tertiary Institutions
- Construction Industries
- Oil and Gas Industries
- Mining Industry
- Beverage Industries
- Aviation Industries
- etc

5.4.2.7 Housing and Transport

Situational Analysis Ghana's Housing Sector

Cement utilization in Ghana had increased from 1.8 million tonnes in 2000 to about 3.2 million tonnes in 2011. More than US$300 million is spent annually on clinker and cementimportation in Ghana. Correspondingly, price of cement had risen from GH¢8.5 in 2008 to about GH¢30.00 in 2018 and continues to increase annually. This high cost of cement and other building materials poses a great challenge to housing delivery, culminating in the current housing deficit of about 1,500,000. This had worsened the housing situation in Ghana leading to squatter communities and slums, especially in the large cities, creating very serious and challenging environmental problems.

(a) Promotion of Local Building Materials (Pozzolana/Burnt Bricks)

The CSIR-Building and Road Research Institute (CSIR-BRRI) has engaged key stakeholders to research into the use of durable indigenous building materials for housing and construction to reduce cost and cut back of imports. To this end, various materials including burnt bricks, pozzolana cement, and other technologies have been successfully developed to help solve the problems of high cost of housing construction.

Adoption of the use of local building materials may lead to:

- affordable housing
- youth employment
- reduced maintenance costs
- savings on importation of building materials

The research emphasis of the CSIR-BRRI is on the need to reduce the dependence on expensive imported cement and rather focus on the production and use of alternative and durable local cementitious materials for housing delivery. This has led to the development of pozzolana from local resources. The positive attributes of pozzolana find expression in its potential to:

- Replace cement by between 30%-40%
- Reduce cost of cement by 18-20%
- Reduce clinker imports, if used commercially, by US$30 million annually, hence, conserving foreign exchange
- Generate employment

The Clay Brick and Tile Industry can provide affordable housing units for the country, which would go a long way to reduce the housing deficit in the country. The use of clay brick products can not only reduce the cost of building materials by 15%, but also offer very low cost of maintenance over the lifespan of the structure. There are well over 120 clay deposit sites across the length and breadth of the country, which have been documented and tested by CSIR-BRRI.

The advantages of using clay products include;
- Job creation, especially for the youth
- Cost saving – reduce imports on building materials
- Low maintenance cost – almost no painting
- Strength of structures (2-25N/mm^2)
- Durable, chemical/water resistance, thermal comfort etc
- Aesthetically pleasing

(b) Provision of Low-Cost Housing

The CSIR-BRRI has, through many years of research, developed the low cost housing technology to introduce the needed competitive in building construction. This technology involves the development of cost indices for construction in Ghana. The evaluation of local clay deposits for possible use in construction and the setting up of brick factories as well as training of brick layers across the country will contribute to the Ghana's socio-economic development agenda. Development of building codes for Ghana, the use of bamboo for housing, and the development of durable building materials from local sources will hold the key to introducing competitiveness in the construction industry.

The job creation avenues that may arise from the use of CSIR-BRRI's technologies are captured in Appendix III.

5.4.2.8 Energy

(a) Waste to Energy Plant (conversion of human, agricultural and market waste using bio digesters to generate electricity for communities)

The CSIR-IIR has developed an integrated energy system of biogas (waste to energy) and solar. The technology is such that communities can be independently powered by solar during the day whilst biogas generated from human, farm, market and animal wastes are used to power the community in the night when solar is not available. CSIR-IIR has designed and installed several solar PV systems. In terms of waste to energy plants, CSIR designed and constructed the waste to energy plant by Jekora (near Legon Farms) which is currently producing pelletised composed from human and market wastes.The CSIR-IIR was also involved in the construction of Safisana waste to energy plant near Ashaiman. Safisana currently produces 100kW electricity and compost. Electricity is sold to local Ashaiman community through power purchase agreement. CSIR-IIR is currently working with Private Enterprise Federation (PEF) to develop the economic case for private sector participation at the district levels. Four Districts are currently under study. The hybrid solar-biomass technology can be deployed at community levels to supply power for the

communities thereby freeing significant electrical power for industry. The solar system is planned to be installed at the village park to provide shade by spectators whilst the waste plant is installed near the waste dump. For Ghana's socio-economic development, communities will provide their own energy whilst freeing electrical power from ECG for industries.

The technology has the following benefits:

1. **Economic:**
   Eliminates the acquisition of expensive solar batteries since the availability of biogas in the night means there is no need to store excess electrical energy in batteries.

2. **Clean Sanitation:**
   Cleaning of the environment: Biogas is generated from human, market, animal and farm wastes. This helps clean the environment and also reduce open defecation.

3. **Improved Agricultural yield:**
   Compost is generated as a by-product which is applied in the farms to improve agricultural yields.

4. **Foreign exchange Earning:**
   Improved Agricultural yield through local production of compost mean reduced or no imports of fertilizer to Ghana thereby saving significant foreign exchange.

5. **Production of Biogas for Economic Use:**
   In addition to the generation of electricity to produce electricity, another advantage is the production of Biogas for other economic uses. To date, CSIR-IIR has constructed well over 70 large digesters in Ghana. Current measurement of biogas from the digesters shows that
   the gas has a purity of over 80%. Further investigation is currently being conducted
   to further purify the gas for use in:
   - lighting,
   - cooking,
   - Vulcanising

5.4.2.9. Science and Technology Information and Science Policy

Two institutes of the CSIR have the mandate for science and technology information dissemination and science policy formulation.

(a) Science and Technology Information

The CSIR-Institute for Scientific and Technological Information (CSIR-INSTI) provides relevant scientific and technological information to farmers, entrepreneurs, research scientists, policy makers and other stakeholders. Information is very essential for conducting day-to-day business, and helps to achieve strategic business objectives. Decision making is made possible because of the availability of the right kind of information, received at the right time, in the right quarters, and by the right person. The sustainable production of food to make Ghana food secure and cut back on the imports of staple food that can be produced locally, depends largely on the extension delivery to farmers and other actors along the value chain. No other institute of the CSIR is better placed to undertake this than the CSIR-INSTI. The Institute has an enviable track-record of implementing successful agricultural extension projects such as the Question and Answer Project, the Ghana Agricultural Information Network System and the Community Radio Project. The Institute has

(b) Policy Formulation

The mission of CSIR-Science and Technology Policy Research Institute (CSIR-STEPRI) is to conduct policy related research to provide knowledge-based information that contributes to the formulation and implementation of policies for socio-economic development on the basis of Science, Technology and Innovation (STI). The research programs focus on the following thematic areas in connecting science and society:

Situational Analysis on Policies

Ghana's 7-year Coordinated Program of Economic and Social Development Policies (2017-2024) has emphasized the need for job creation, prosperity and equal opportunity for all. Currently, Ghana's unemployment rate is estimated at (5.77% as of 2016). Ghana's socio-economic development agenda has a bearing on job creation and increased local participation in its industrialization pillar of national development. Ghana's socio-economic development is a gradual weaning off development assistance and increasing internal revenue mobilization for development financing. In this regard, efficient management of Ghana's resources, focusing on value addition to its raw materials and greater involvement of the private sector in the socio-economic development of the country is critical.[21]

Up until now, the state involvement in R&D Investments has been low thus leaving research in the hands of donors and development partners. Government of Ghana funds: 90-98% for personal emoluments; 2-8% for administrative expenditure; and less than 1% for direct research. The level of uptake of research findings in the Agriculture sector has been low due to the low farmer extension ratio of 1:1500 in Ghana. Low agricultural productivity, high post-harvest losses and low value addition could be attributed to low application of STI in the entire agricultural value chain. Currently, MOFA is implementing a Policy on "Planting for Food and Jobs" which is expected to increase maize production by 30%, rice by 49%, soyabean by 25% and sorghum by 28% within 4-year period. Under the Planting for Food and Jobs programme, GOG is committed to the provision of improved seeds, supply of fertilizer, provision of dedicated extension services, a marketing strategy, and the use of e-agriculture. [21]

Table 2: The yield gap between achievable and actual yields

Crops	Actual Average Yield (Mt/Ha) 2014	Actual Average Yield (Mt/Ha)	% Achieved
Cassava	18.30	48.70	37.60
Plantain	10.80	20.00	54.00
Yam	16.80	49.00	34.30
Cocoyam	6.50	8.00	81.30
Maize	1.73	3.5-7.5	15.72
Rice	2.60	4.00-8.00	43.33
Millet	1.0	2.00	50.00
Sorghum	1.1	2.00	50.00

The CSIR-STEPRI has been involved in the formulation of quite a number of policies and policy related activities as under-listed below and some highlights specifically on potential contribution to the Ghana's socio-economic development agenda:

- CSIR-STEPRI has been involved in the planning process of Science Agenda for Agricultural (S3A) Development. This aims at mainstreaming STI into National Agriculture and Food Security Investment Plan (NAIPS). The process requires institutional and capacity building particularly for implementation and evaluation of policies. The National consultation processes brought out key developmental challenges such as land and tenure security, low awareness of threats posed by climate change, weak linkages and poor institutional coordination and challenges with market access and trade as well as the changing preferences of consumers. CSIR- STEPRI has conducted studies in rice-producing areas and has proposed strategies for developing the rice value chain. CSIR-STEPRI has also developed a marketing and promotional strategy for locally produced rice. Key recommendations in the strategy are increasing investment in rice production, milling, processing, and promotion. The role of CSIR-STEPRI will be to disseminate the promotional strategy and support its implementation.
- Ghana's socio-economic development will require some reasonable levels of protection regarding imports (poultry and rice for example; about 65% - 680,000 tonnes annually - of rice consumption is imported). This also requires increasing the domestic production and quality of rice and poultry as well as changing people's mind-sets and negative perceptions about local rice. CSIR-STEPRI has developed a marketing and promotional strategy for locally produced rice. CSIR-STEPRI can conduct tracking of progress on STI application in the Agric sector using participatory monitoring and stakeholder engagement and consultation approaches.
- The CSIR-STEPRI was involved in the development of the National Climate Smart

Agriculture Action Plan (2016-2020) which throws light on the need for water conservation and irrigation systems for enhanced agricultural productivity in the Savannah Zone and the need for the development of livestock production systems and capacity development for the transition and forest zones respectively. There is the need to take a second look at the irrigation policy, and the CSIR-STEPRI is in a better position to undertake the review of the policy.

- The CSIR–STEPRI can also conduct needs assessment and market identification (feasibilities) studies to support private sector development. In the past a feasibility study was conducted for Teledata ICT Company. Expertise exist in the Institute to assist industry in this regard especially to support one district one factory concept
- CSIR-STEPRI has been involved in Rural Enterprises Project (REP) projects aimed at using a district-based model for development in terms of access to business development services, rural financing through participating financial institutions and technology transfer through the rural technology facility to Medium and Small-scale Enterprises (MSEs). Under the projects, Business Opportunities Identification Survey (BOIS) was conducted in 95 districts in Ghana in two phases. Agro-processing, farm based activities and service enterprises dominated the existing businesses identified. The top three most important limiting factors or constraints to businesses development identified include inadequate capital, inefficiencies in financial management and low technology applications.
- With the current industrialization strategy of one-district-one factory, consideration is given to locally owned businesses for government necessary support. About 173 businesses with plans are ready for support. About 46% are in the agro-processing industry (e.g. Amantin Agro Processing Plant, Asikess Ventures Limited and Adaklu Agro Processing Plant) and 36% into manufacturing.
- CSIR-STEPRI's Role in evidence-based research for policy making, CSIR-STEPRI played a unique role in generating research evidence for policy making under its Development Research and Uptake in Sub-Saran Africa Project which was implemented in 2014-2017. STEPRI worked with key sectors of the economy including Agriculture, Trade and Industry and the Ministry of Environment Science and Innovation (MESTI). The experiences gained in the facilitation role to bring researchers/academia and policy makers together for effective dissemination of evidenced based research for policy making can be extended to current government initiatives. Through CSIR-STEPRI's work on Agricultural Science and Technology Indicators (ASTI), data and analytics are generated on the structure, status, funding and institutional capacity for agricultural development.[17]

The use of science technology and innovation is at the center of the government's effort to improve socio-economic performance of the country. As stated in the Coordinated Programme of Economic and Social Development Policies (2017-2024), there is dysfunction in collaborations between public research institutions and business on product, service and process innovation, against the fact that it is an area with prospects for product and industrial development, as well as job creation.

The need to fully utilize the expertise of researchers in national development and more so from the perspective of '*Ghana's socio-economic development, the role of CSIR-STEPRI*' is critical. Key strategic actions with CSIR-STEPRI's involvement that will facilitate effective impact pathways towards Ghana's socio-economic development include the:

- Development of Innovation policies in selected fields;
- Undertake Innovation Studies on new products from industries and local people;
- Promote access to technical facilities and services to support local climate adaptation and mitigation solutions;
- Track progress of STI application in all sectors of the Ghanaian Economy;
- Improve research uptake and utilization framework;
- Improve on science communication;
- Stronger collaboration with universities and the Academy of Arts and Sciences; and
- Strengthen Industry interactions with research.

Challenges and Constraints

- Limited funding for STI activities
- Lack of policy backing for most of the STI outputs generated by the CSIR
- Encroachment of CSIR research land
- High attrition of scientists
- Lack of respect for scientists

Despite the growing strength of these motivations, many barriers to university-industry collaboration persist, including the following:

- There is an inherent mismatch between the research orientations of industry and research institutions, with an excessive focus on fast commercial results by industry and on basic research in research institutions.
- Collaboration is costly and the returns only accrue in the medium to long run, but industry seek short-term results and clear contributions to current business lines.
- In terms of outputs, industries are usually interested in how quickly new patents or new products can be obtained, and want to delay publications to avoid disclosing information. Research institutions, in contrast, are typically motivated to publish research results as fast as possible.
- Industry is concerned about secrecy and misalignment of expectations with regard to intellectual property (IP) rights and making a profit from them. Thus agreements need to be established in a commercially timely manner that ensures the ability to commercialize with appropriate returns.
- Difficulties in negotiating a collaboration include lack of information, difficulties, finding contact persons, and transaction costs of finding the right partner, among others.

5.5 Roles and responsibilities of Research Institutions, Industry andUniversities within the ecosystem

5.5.1 Introduction

Cooperation in research, development and innovation (RD&I) between universities and/or research institutes and industries plays a fundamental role in the economic development of a country. Industry benefits from state-of-the-art laboratories and technologies from academia, while institutes learn about

business reality and market needs.

The government plays a fundamental role in making R-I-U a reality, and many governments around the world have developed policies and initiatives to encourage such collaborations by supplying funding for joint research projects, offering tax incentives for research and development, and creating innovation hubs and technology parks. Government policies have a significant impact on the nature and extent of collaboration between universities, research and industry.

The role of the academic/research institutions is to generate scientific knowledge in collaboration with industry for the economic growth of a nation. Collaboration between highly qualified academics/researchers and professionals in industry could boost local economies by combining all existing technical skills and capabilities.

Industry depends on partnership with such institutions to ensure competitiveness in the market place, either through innovation produced directly or through the training of human resources. The high cost of sophisticated laboratory equipment, the difficulty of access to international research and development centres, and the risks associated with innovation tend to impose severe limitations on the investment of companies in RD&I. Hence the provision of such input fall on the Research Institutions supported by the government.

In order for R-I-Us to thrive, industry needs to learn to work outside the boundaries of their organization and to develop capabilities to interact and cooperate with partners that have different characteristics, which is to say that they have to manage their relationships. Academics/Researchers and their peers in industry will need to learn from experience throughout the partnership period, especially during the first interaction when participants discover the norms and culture of the disparate organizations, with the necessity to reconcile differences, to reach a common understanding and to build trust.

5.5.2 SWOT Analysis of Science, Technology and Innovation in Ghana - Lessons for the Policy constraints and challenges

Progress made over the years indicate that there have been some inherent strengths in the STI policies. However, a number of challenges remain. One factor that affected the development of science and technology was lack of skilled workers due to the educational system. Research funding allocations by governments were not adequate to address the needs of providers of science and technology services (i.e. the research institutes and universities) so as to impact industry. The universities and training institutions did not produce enough graduates with superior capabilities and drive to start new businesses and spur innovation. Given the scarce national resources, there is a need to identify unique areas of activities where the limited resources could be efficiently deployed.

The SWOT analysis of System of Science and Technology Innovation in Ghana (UNCTAD, 2011) is presented in Appendix I

5.5.3 SWOT Analysis Results

Three areas of interest identified to improve the delivery of STI in Ghana based on the SWOT analysis are the following:

I. Prioritization of Opportunities that give Highest Competitive Advantage;
II. Prioritization of Strengths that give Highest Competitive Advantage; and
III. Prioritization of Weaknesses which when resolved create significant Competitive Advantage

Opportunities available to the STI Ecosystem which could be galvanized and taken advantage of were identified and actions needed to make them competitive recognized. Similarly, Strengths in the ecosystem already usable were identified and actions needed recognized. Weaknesses inherent in the ecosystem were identified and actions needed to improve upon them recognized. (See Appendix II).

5.6 Strategic Thrusts and Operational Strategies

From the SWOT analysis undertaken the following four (4) strategic thrusts and their specific objectives are derived as the critical areas needing attention in order to leverage the R-I-U ecosystem to a level that positions it to impact significantly on the socio-economic development of the country as shown below.

Fig. 10. Strategic Thrusts and their Objectives

Strategic Thrust 1	**Industry Driven R&D and Technological Innovation:**	To develop and transfer at least one (1) industry-driven technology (of relevance to the local economy) per each Research institution/University per year.
Strategic Thrust 2	**Improve Visibility of the STI Ecosystem:**	To ensure that the activities of the Scientific community is positively visible through regular appearances in the print and electronic media; and enjoys significant goodwill from its identified stakeholders through interactions.
Strategic Thrust 3	**Financial Resources Mobilization:**	To resource the research institutions and universities through: IPR operationalisation; entrepreneurial capacity development; attraction of funds from industry for research; and funds for consultancy services and public private partnerships.
Strategic Thrust 4	**STI Ecosystem Performance Improvement:**	To enhance performance through sensitisation and motivation as well as ensuring a robust and effective Monitoring and Evaluation system.institution/University per year.

5.6.1 Strategic thrust 1: Industry driven R&D and Technological innovation

The relevance of the STI Ecosystem will be effectively assessed by the extent to which its technologies resolve industry challenges and increase their contribution to national GDP. Technology development thus needs to be targeted to specific industry needs and discussed with industry partners for validation. Education and training systems to put emphasis on science and engineering training. Regional Science parks and Business Incubation Centers to be established to share knowledge from research-industry-universities, test the technologies developed with the industry partners and promote innovations for commercial/industrial uptake.

5.6.2 Strategic thrust 2: Improve Visibility of the STI Ecosystem

A positive national and international visibility of the STI Ecosystem is critical to the image of the country. The extent to which the ecosystem attracts favourable responses to its legitimate entitlements, concerns and achievements from key stakeholders will be based on its visibility. This could be achieved through a number of initiatives. First the strengthening of PR Systems in all research and universities would be key in driving their visibility. Regular meetings to be conducted with stakeholders aligned to each institution, and a stakeholder management strategy implemented to address the interests of the various categories of stakeholders. Open days and exhibitions to be organized to showcase the achievements of the STI Ecosystem. Informative documentaries, brochures, flyers, newsletters, pamphlets, and other promotional materials to be developed and disseminated before, during and after these open days. Publication of feature articles and participation in radio, TV and other media talk shows to be undertaken to contribute significantly to increase their media exposure. The organization of regular STI Awards Nights and to reward scientists, technologists, innovators, industry partners, etc., as well as the institutionalization and operationalization of an annual RD&I Policy lectures to educate public on RD&I issues concerning the STI Ecosystem would further enhance the visibility.

5.6.3 Strategic thrust 3: Financial Resources Mobilization

The heartbeat of any organisation is the financial resources it has at its disposal to procure the factors of production needed to implement programmes aimed at achieving its organisational goals. Various strategies have to be put in place to ensure that funds are continually mobilised to drive the agenda of the STI Ecosytem. Transfer of technologies developed to be improved by strengthening current IPR, PR and marketing functions to effectively deliver and aggressively promote uptake of technologies & services by local industries. Practical steps would be pursued to patent/copyright all marketable technologies developed in the country. The high level of technical competency of the workforce will be complemented with entrepreneurial skills in order to leverage the performance of the STI Ecosystem in a holistic manner. It is hoped that these entrepreneurial capacity development efforts would translate into financial benefits for the country.

5.6.4 Strategic thrust 4: STI Ecosystem Performance Improvement

Effective performance of ecosystems is key to continual improvement; and a strong, well-resourced M&E will ensure effective tracking of performance and bring about timely corrective measures to achieve results. The M&E system within the R-I-U would be strengthened and resourced to tract performance and advice on necessary actions to take. The system would then be used to objectively track, measure and evaluate the performance of all systems, staff and activities of the STI Ecosystem within and beyond the context of this blueprint.

5.7 Strategic Actions

The Strategic Actions needed for smooth take off for the four strategic Thrusts involving their outputs, action to be taken, the timeframe and the institutions and individuals to be responsible are presented below:

Table 3. Action Plan for Strategic Thrust 1: Industry Driven R&D and Technological Innovation

Objective: To develop and transfer at least one (1) industry-driven technology (of relevance to the local economy) per each Research institution/Universities per year.							
Outputs	**Actions**	**Time Frame (Year)**					**Lead Responsibilty**
		1	2	3	4	5	
Output 1.1 At least 20 technological needs approved by industry to address 20 identified industrial needs, each year.	**Activity 1.1.1** Identify annually industry needs in each of the following: • Food Security and Poverty reduction • Climate Change, Environmental Management and Green Technology • Material Science and Manufacturing • Energy and Petroleum • Bio-medical and Public Health • Electronics and ICT • Any others	—	—	—	—	—	**Technical Sub-Committee members of the Implementation Committee**
	Activity 1.1.2 Assessment of the suitability of the technologies and innovations identified.	—	—	—	—	—	
	Activity 1.2.3 Facilitation of the approved technologies and innovations identified.	—	—	—	—	—	

Outputs	Actions	Time Frame (Year)					Lead Responsibilty
		1	2	3	4	5	
Output 1.2 At least 20 industry driven technologies developed for testing and validation, each year.	**Activity 1.2.1** Initiate transfer of the identified technologies and innovations approved by industry.						**Technical Sub-Committee members of the Implementation Committee**
	Activity 1.2.2 Package technologies and innovations in industry-friendly formats.						

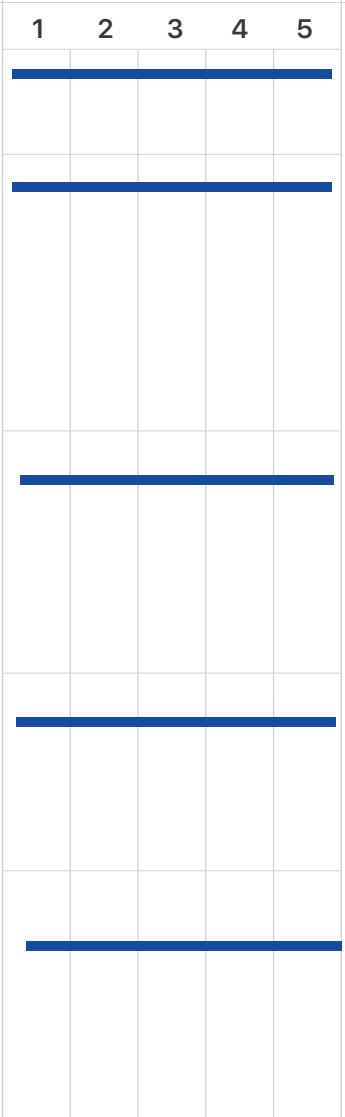
Table 4. Action Plan for Strategic Thrust 2: Improve Visibility of the STI Ecosystem

Objective: To ensure that the activities of the Scientific community is positively visible through regular appearances in the print and electronic media; and enjoys significant goodwill from its identified stakeholders through interactions.

Outputs	Actions	Time Frame (Year)					Lead Responsibilty
		1	2	3	4	5	
Output 2.1 PPP arrangements established with at least 20 industries	**Activity 2.1.1** Develop Guidelines for a Public-Private Sector Partnership Agenda and Strengthen PR Systems in the STI Ecosystem						**Technical Sub-Committee members of the Implementation Committee**
	Activity 2.1.2 Operationalise a Public-Private Sector Partnership Agenda to effectivelynengage with industry and other relevant government agencies on a regular basis.						
	Activity 2.1.3 Conduct meetings regularly with identified stakeholders						
Output 2.2 Increased Stakeholder Engagement and Media Exposure.	**Activity 2.2.1** Implement a stakeholder management strategy that addresses the interests of the various categories of Stakeholders of the STI Ecosystem						**Technical Sub-Committee members of the Implementation Committee**

Outputs	Actions	Time Frame (Year)					Lead Responsibilty
		1	2	3	4	5	
	Activity 2.2.2 Develop and disseminate informative documentaries, brochures, flyers, newsletters, pamphlets, and, other promotional materials.						**Technical Sub-Committee members of the Implementation Committee**
	Activity 2.2.3 Participation in Radio and TV talk shows and publication of feature articles.						
Output 2.3 Webometrics ranking of the STI Ecosystem improved to at least the best 10 in five years.	**Activity 2.3.1** Enhance visibility by improving content quality of the Website of the institutions to increase the external links that the organizations web domain receives from third parties.						**Technical Sub-Committee members of the Implementation Committee**
	Activity 2.3.2 Improve Website activity by increasing total number of webpages hosted in the main web domain (including all th subdomains and directories)						
	Activity 2.3.3 Improve Openness by increasing the number of rich files (pdf, doc, docx, ppt) published in dedicated websites						
	Activity 2.3.4 Improve excellence by increasing the number of academic papers published in high impact international journals.						

Table 5. Action Plan for Strategic Thrust 3: Financial Resource Mobilisation.

Objective: To resource the research institutions and universities through: IPR operationalisation; entrepreneurial capacity development; attraction of funds from industry for research; and funds for consultancy services and public private partnerships			
Outputs	**Actions**	**Time Frame (Year)**	**Lead Responsibilty**
Output 3.1 Attraction of funds through submission of winning proposals, bidding for consultancies, sale of research by-products and technology development for industry.	**Activity 3.1.1** Develop and submit winning proposals to industry for funding. **Activity 3.1.2** Identify and bid for relevant consultancy services; whilst lobbying government to get at least 20% of government jobs related to STI. **Activity 3.1.3** Develop and submit technical and financial proposals to industry for funding to address identified industrial needs. **Activity 3.1.4** Develop and implement a marketing plan for the most marketable research by-products. **Activity 3.1.5** Establish a competitive system for pricing products and services as well as budgeting for projects and consultancies.		**Technical Sub-Committee members of the Implementation Committee**
Output 3.2 IPR Policy operationalised for effective commercialisation.	**Activity 3.2.1** Audit current IPR, PR and marketing functions and strengthen them to effectively deliver and aggressively promote uptake of technologies & innovations. **Activity 3.2.2** Establish strong beneficial business relationships and partnerships with industry to commercialise copyrighted/patented technologies.		**Technical Sub-Committee members of the Implementation Committee**

Outputs	Actions	Time Frame (Year)	Lead Responsibilty
	Activity 3.2.1 Continually audit to identify technologies and innovations that can beat competition and pursue practical steps to patent them.	1 2 3 4 5	
Output 3.3 **STI Ecosystem Staff trained in relevant entrepreneurial activities.**	**Activity 3.3.1** Continually identify entrepreneurial capacity development needs of different categories of staff in the ecosystem. **Activity 3.2.2** Identify and actively engage potential sources for entrepreneurial capacity development, and assess cost and content of training vis-a-vis needs. **Activity 3.3.3** Identify and actively engage potential sources for entrepreneurial capacity development, and assess cost and content of training vis-a-vis needs.		**Technical Sub-Committee members of the Implementation Committee**

Table 6. Action plan for Strategic Thrust 4: STI Ecosystem Performance Improvement

Objective: To enhance performance through sensitisation and motivation as well as ensuring a robust and effective Monitoring and Evaluation system.			
Outputs	**Actions**	**Time Frame (Year)**	**Lead Responsibilty**
Output 4.1 Improved STI Ecosystem Staff motivation and performance.	**Activity 4.1.1** Conduct annual situational analysis (HR Climate survey) to identify causes of poor attitudes and the lack of motivation amongst the STI Ecosystem and address them.	1 2 3 4 5	**Technical Sub-Committee members of the Implementation Committee**
	Activity 4.1.2 Audit existing remuneration, incentives, and Award Schemes to identify shortfalls, improve and enhance effective operationalisation.		
	Activity 4.1.3 Develop and implement a system for seeking opinions on issues before decision making and ensuring effective communication and feedback at all levels.		
	Activity 4.1.4 Identify professional development needs of the ecosystem and develop and implement training programmes to address them.		
Output 3.2 IPR Policy operationalised for effective commercialisation.	**Activity 4.2.1** Audit and capacitate an effective Monitoring and Evaluation Unit within the ecosystem.		**Technical Sub-Committee members of the Implementation Committee**
	Activity 4.2.2 Audit current reporting systems for all result-oriented activities within the ecosystem and improve upon them for robustness and effectiveness.		

5.8 Strategic thrust Indicators for the Implementation of the blueprint

Performance Indicators and Targets for the Research Institutions and the Universities within the Ecosystem.

Table 7. Strategic Thrust 1 Indicators

Strategic Thrust 1: Industry Driven R&D and Technological Innovation			
Indicator		Targets	
		5-Years	Yearly
Indicator 1.1a:	Number of identified industrial needs. At least 2 from each of the R-U institutions (eg. CSIR, GAEC, UG, UMAT, KNUST)	100	20
Indicator 1.2:	Number of industry driven technologies developed. At least 2 from each of the R-U institutions (CSIR, GAEC, UG, UMAT, KNUST)	100	20
Indicator 1.3:	Number of industry driven technologies validated and adopted by industry. At least 2 from each of the five institutions (CSIR, GAEC, UG, UMAT, KNUST)	100	20

Table 8. Strategic Thrust 2 Indicators

Strategic Thrust 2: Improve Visibility of the STI Ecosystem			
Indicator		Targets	
		5-Years	Yearly
Indicator 2.1:	Document detailing Guidelines for a PPP agenda.	1	1
Indicator 1.2:	Number of private sector actors with whom PPP arrangements have been established. At least 5 per each R-U institution	125	25
Indicator 2.3:	Number of identified stakeholders whose interests have been addressed. At least 2 per each R-U institution per year)	50	50
Indicator 2.4:	Number of informative promotional materials distributed to stakeholders.	50	50
Indicator 2.5:	Number of TV/radio talk show programmes participated in. At least 10 appearances per each R-U institution	250	50
Indicator 2.6:	Number of feature articles published.	100	20

Table 9. Strategic Thrust 3 Indicators

Strategic Thrust 3: Financial Resource Mobilisation			
Indicator		**Targets**	
		5-Years	**Yearly**
Indicator 3.1:	Amount attracted through the provision of consultancy services. At least GHC15.00m per each R-U institution per year	GHC 375.00m	GHC 75.00m
Indicator 3.2:	Amount attracted through development of technologies for solving industry problems. At least GHC 10.00m per each R-U institution per year	GHC 250.00m	GHC 50.00m
Indicator 3.3:	Amount generated through the sale of Research By-Products. At least GHC 5.00m per each R-U institution per year	GHC 125.00m	GHC 25.00m
Indicator 3.4:	Number of technologies patented/copyrighted. At least 10 per R-U institution per year	250	50
Indicator 3.5:	Number of private sector actors partnering the Scientific community to commercialise copyrighted/patented technologies	100	20

Table 10. Strategic Thrust 4 Indicators

Strategic Thrust 4: STI Ecosystem Performance Improvement			
Indicator		**Targets**	
		5-Years	**Yearly**
Indicator 4.1:	Poor attitudes and lack of motivation identified to improve performance. At least 10 per each R-U institution per year.	250	50
Indicator 4.2:	Poor attitudes and lack of motivation addressed and reviewed annually to improve the system. At least 10 per each R-U institution per year.	250	50
Indicator 4.2:	Attractive Incentive and award schemes available. At least 10 per each R-U institution per year	250	50
Indicator 4.7:	Copy of comprehensive, robust and effective M&E system developed for the Ecosystem.	250	50
Indicator 4.8:	Annual performance assessment reports on the STI Ecosystem. One per each R-I-U.	100	20

Chapter 6

UK-Ghana Science, Technology & Innovation Strategy 2023 – 2027 (Brief Report)

6.1 Introduction

The UK and Ghana have a strong history of working together in science, technology, and innovation (ST&I) and can count scores of current, ongoing partnerships. The UK enjoys a reputation as a global leader in ST&I and has ambitions to further its impact through international partnerships. Ghana also has a thriving ST&I community driving innovation in financial services, agriculture, and medical research, to name a few. As the UK and Ghana renew their commitments to advancing ST&I, it is envisioned that a sustainable partnership will be founded on mutual respect, transparency, and shared knowledge. ST&I is a foundation of national well-being, needed for the health, wealth, prosperity and security of the citizens. This joint strategy puts forward ambitions for making more collaborations in the public and private spheres and sets out how this could be achieved.

6.2 Objective

To increase the number, quality and impact of UK-Ghana ST&I partnerships.

6.3 Strategy

The strategy is based on the understanding that opportunities can be missed, and impacts limited by poor knowledge and coordination across actors in the ST&I space. Improvement is possible by better understanding the landscape, coordinating related efforts, creating opportunities to develop and exploit new partnerships, and tackling the obstacles that sometimes get in the way.

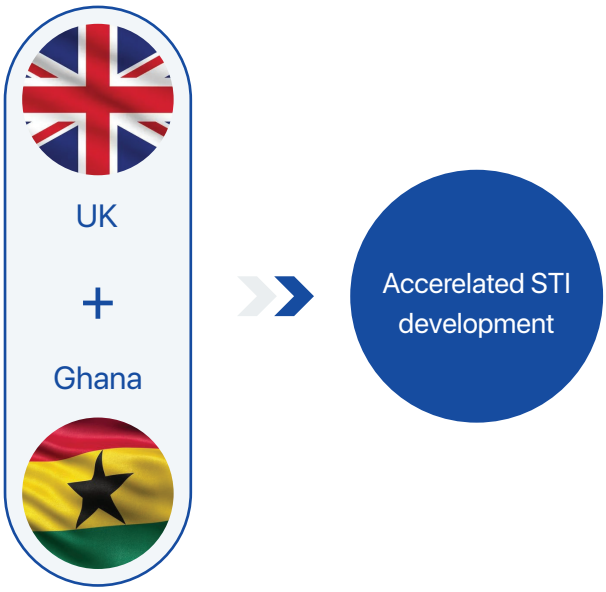


Fig. 11 UK-Ghana Partnership

6.4 Priority Actions

A. Deploy UK and Ghana expertise to shape stronger ST&I related policies and ecosystem institutions.
B. Help consortia and networks to better track opportunities.
C. Foster capability building programmes, emphasising knowledge transfers.
D. Continue to promote, facilitate, and establish joint university / research institute partnerships that encourage open science practices.
E. Support actors in adopting data management and key technologies.
F. Explore smart ways to partner investors with innovators.
G. Help business development training programmes to spread the use of best business practices.

6.5 Principal pillars

The approach will be guided by four principal strategic pillars:

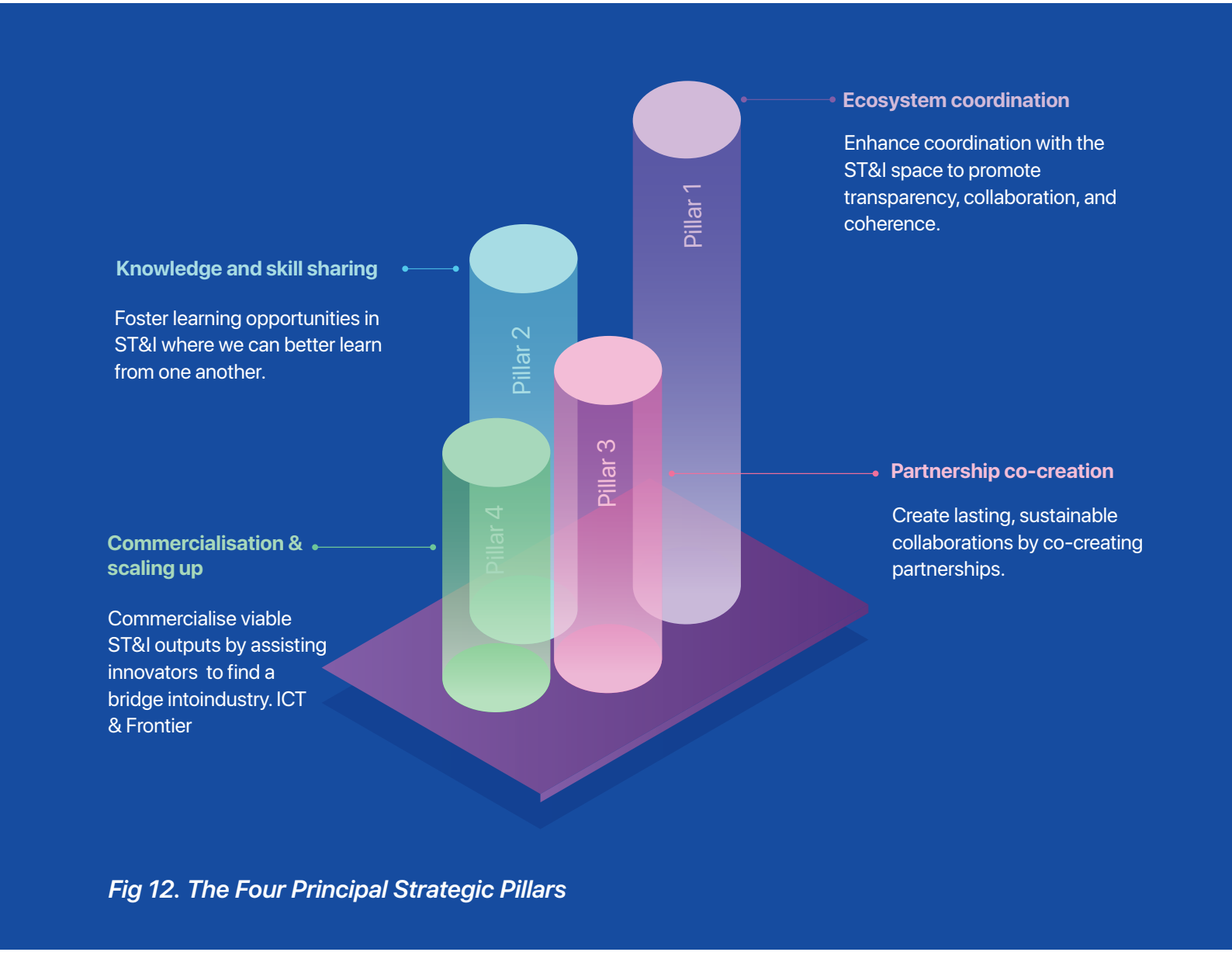


Fig 12. The Four Principal Strategic Pillars

6.5.1 Pillar 1: Ecosystem coordination

Poor networks and information flows can stop investors, researchers, and innovators from making the most of their work, so a concerted effort needs to be made to cohere and strengthen Ghanaian ST&I ecosystem, and UK-Ghana links. This will enable UK partners, investors, and innovators to introduce themselves more effectively and widely to the Ghanaian market, and vice versa. Mapping and tracking stakeholders in both nations should be conducted regularly and the resultant data availed on open platforms such as MODARI (in line with confidentiality and data protection restrictions) to enable new actors to easily access existing networks.

Initial programmes and work may include:

- Utilising existing groups (such as the UK-Ghana Business Council and UK-Ghana Investor Group) to map and track UK-Ghana opportunities and existing partnerships, maintaining an up-to-date network of key contacts accessible through open channels (such as UK-Ghana Chamber of Commerce; Council for Scientific and Industrial Research).
- Leveraging UK and Ghana experience and expertise to shape stronger ST&I related policies and eco-system institutions.
- Promoting the use and coordination of innovation hubs across Ghana, such as the existing Kumasi Innovation Hub and the Ghana Innovation and Research Commercialisation Centres.

Spotlight on Success:
Ghana Innovation Hub and Leeds University Business School are together developing and delivering training for Ghana and Africa's tech and innovation eco-system builders. The Executive Programme in Entrepreneurial Ecosystem Leadership is co-designed and delivered in Leeds, targeting policy makers and enterprise support organisations, giving participants the skills to assess their local eco-system and find ways to make it better.

Sectorial focus:
- Agriculture,
- Agritech,
- Sustainability,
- Public Policy,
- Energy,
- Manufacturing

6.5.2 Pillar 2: Knowledge and skill sharing

The UK and Ghana can learn from each other better. Education and awareness of science and technology in the wider population is key to progress in ST&I. Sharing ideas and collaborating is important at every educational level. There are gaps around PhD offerings and R&D capability to help prepare and upskill the next generation of innovators in Ghana. Meanwhile, UK academia, private and public sector organisations must have the opportunity to learn from their Ghanaian counterparts through knowledge sharing programmes, if they are to successfully engage with African markets.

Initial programmes and work may include:

- Supporting Science Tech Engineering and Maths (STEM) throughout the education systems by partnering institutions at various levels to conduct curriculum development and review and build capacity in teaching.
- Fostering capability building programmes around health safety research and practices. This could be piloted with animal health and sanitation, a key sector for pandemic prevention and to promote global security, highlighting water, sanitation, and hygiene (WASH) interventions.
- Continue promoting, facilitating, and establishing joint university partnerships that reinforce Ghana's biotechnology industry and encourage open science practices.

Spotlight on Success:
Ocean Country Partnership Programme (OCPP) OCPP works with Ghanaian and UK academic institutions and specialised government agencies to support Ghana's Sustainable Ocean Plan by strengthening marine science expertise; developing science-based policy and

and management tools; creating educational resources. It is also building national and community level monitoring systems and the use of technology to tackle illegal fishing. OCPP will support a regional marine litter research programme as well as funding 10 MSc's hosted at Ghanaian universities with support from UK academic partners.

Sectorial focus:
- Health safety,
- Best practices,
- Vaccine development and production,
- Biotechnology,
- Digitalisation,
- Education,
- R&D

6.5.3. Pillar 3: Partnership co-creation

The UK and Ghana already enjoy a remarkable number of ST&I partnerships. This strategy will help create more, and prioritise equitable benefits and decision making. This is well modelled by several universities and research institutes in the two countries but should be continuously supported, encouraged and extended across all public and private spheres. Members of these partnerships can learn from each other what works best.

Initial programmes and work may include:
- Supporting new academic partnerships in the two countries, with a focus on frontier technologies such as AI.
- Host a science engagement series to share current findings and ongoing research as well as allow innovators and investors to identify each other. The first of this series will be around AI.

Spotlight on Success:
Dundee University – Ghana Drug Discovery Hub, The Wellcome Centre for Anti-Infectives Research and the Drug Discovery Unit from the University of Dundee are working with five Ghanaian universities and research institutes, including the Noguchi Institute, to establish a Drug Discovery Hub in Ghana. It is making the most of UK's world class expertise and Ghana's deep experience in researching some of the world's most important diseases. It is attracting funding from widespread sources including a major grant from Bill and Melinda Gates Foundation to develop new antimalarials.

Sectorial focus:
- Artificial Intelligence,
- Business Development,
- Digitalisation,
- Private Sector,
- Technology, media and telecom

6.5.4. Pillar 4: Commercialization & scaling up

6.5.4. Pillar 4: Commercialization & scaling up
Researchers and innovators often struggle to commercialise their inventions and protect intellectual property (IP). Access to finance and industry backers is particularly challenging in Ghana. New ways must be explored to build partnerships between investors/ businesses, and researchers / innovators, and share best practice on IP systems.

Initial programmes and work may include:

- Utilising existing initiatives to partner investors and innovators (such as the UKGBC or Investor Group) and promote attendance at networking conferences (such as the African Tech Summit and the UK-African Investment Summit).

- Establishing business development training programmes to spread the use of best business practices globally.
- Continuing to showcase success stories of commercialisation and scaling-up journeys involving GH and UK partners that have resulted in mutual or shared benefits.

Spotlight on Success:
Transformation Energy Access (TEA) is an FCDO and Shell Foundation research and innovation platform supporting testing and scale-up of new technologies in affordable and clean energy. 'Kofa Technologies' is using the fund to test and scale its network of portable, swappable batteries for electric motorcycles and stationary backup power needs in Ghana. It aims to reach 10 million customers in Africa and offset 10 million tonnes of carbon dioxide emissions per year.

Sectorial focus:
- Artificial Intelligence,
- Blockchain,
- The Cloud,
- Machine Learning,
- Natural language processing,
- Regulation

6.6. Implementation and next steps

This strategy will be led by British High Commission in Ghana (BHC) and Ghana's Ministry of Environment, Science, Technology, and Innovation (MESTI) who will monitor implementation, jointly preparing a progress report each year. BHC and MESTI will work closely with other Ministries and Agencies (such as Ghana's Ministries of Education and of Communication), universities, and networks in their respective countries. A steering committee of leading actors will be appointed by the two governments to oversee and advise on the strategy's execution and review.

Chapter 7

Implementation Committee

7.1 Introduction

There is the need to have an inter-ministerial governing body from the following Ministries: Ministry Environment Science Technology and Innovation (MESTI), Ministry of Trade & Industry (MoTI), Ministry of Education (MoE) and Ministry of Finance (MoF). The respective Ministers or their Chief Directors, or Heads of agencies and departments of the above Ministries would provide the overarching political oversight. There should be an Implementation Committee made up of stakeholders / technical members to provide technical direction for implementation of the actions. These should be drawn from the CSIR, the Universities, Tertiary Education Sector of the Ministry of Education, Association of Ghana Industries (AGI), Ghana tertiary Education Commission (GTEC), Youth Enterprise Agency (YEA).

The Public research institutions, some selected industries and the Science based universities will play major roles in developing appropriate locally needed technologies as well as absorbing key foreign technologies and transmitting them to Ghanaian conglomerates. The selected industries to be part of the startups should receive significant guidance and support from the government via subsidized loans, specific licenses to enter target industries and protective regulations. It is hoped that the needed resources and governance regimes would enable the full implementation of this blueprint, in such a manner as to ensure that the R-I-U collaboration will function smoothly to create wealth and jobs.

7.2 Terms of Reference for Oversight Committee

The Oversight Committee of the Research-Industry-University Collaboration will investigate and report on matters that ensure the collaboration meet the needs of a present and future labour force focused on innovation and creativity. The Committee must have particular regard to:

1. the extent to which students are graduating with the skills needed for jobs of today and of the future;
2. laws and regulations that may act as barrier to education providers being able to offer qualifications that meet the needs of industry and by extension the economy;
3. factors that encourage closer partnerships between industry, in particular small and medium enterprises; the research institutions and the universities, including but not limited to:
    - intellectual property;
    - technology transfer;
    - postgraduate training practices; and
    - rapid commercialisation;
4. opportunities for generating increased economic activity, including further investment and jobs, through greater synergies among publicly funded research agencies (such as the CSIR), universities and with industry. Areas of synergies to include co-location, cluster formation and development of precincts between such institutions and industry;
5. relationships between tertiary education entrepreneurship programmes and public, private, and not-for-profit incubators and accelerators; and
6. other related matters that the Committee considers relevant.

7.3 Composition, roles and responsibilities of Committee members

The membership of the Committee should be selected from the following bodies:

a) Council for Scientific and Industrial Research
b) Universities / Tertiary Education Sector of the Ministry of Education
c) Association of Ghana Industries
d) Ghana Tertiary Education Commission
e) Youth Enterprise Agency
f) Ministry of Trade & Industry
g) Ministry of Environment Science Technology and Innovation
h) Ministry of Education
i) Ministry of Finance

The Implementation Committee when in place will have to set up Sub-Committees for specific functions and activities. Such Sub-Committees may include:

- Technologies developed for transfer
- Innovations
- Training
- Intellectual Property Rights
- Commercialization
- Finance
- Monitoring and Evaluation

7.4 Guidance for reporting – KPIs and M & E.

7.4.1 Key Performance Indicators (KPIs)

Key Performance Indicators (KPIs) are a way to measure whether or not a company is achieving its goals. This can include anything from financial metrics (revenue, profitability, etc.) to operational measures (customer satisfaction, team member productivity, etc.). KPIs can be different for every company, depending on what goals they're trying to achieve.

A tech startup might have different KPIs than a traditional manufacturing company. But no matter what industry one is in, KPIs are a valuable and vital tool to gauge the company's success.[21]

For this blueprint some KPIs to be considered are Cash flow; Customer satisfaction; Customer retention rate; Labour productivity; Quality of products and/or services; Process time; Employee development; and Employee knowledge.

a. Churn Rate

One of the biggest threats to any startup is a high churn rate. This happens when customers leave your service either because they're unhappy with it or because they've found a better option elsewhere. Tracking the churn rate will help you identify and address any problems with your product before too many customers leave. The attrition rate or customer churn, commonly referred to as the churn rate, is the frequency with which customers discontinue doing business with a company. The most popular way to express it is as the percentage of service subscribers that cancel their memberships within a predetermined time frame. It is also the frequency of employees quitting their positions within a predetermined time frame. A company's growth rate (determined by the number of new customers) must be higher than its attrition rate to grow its customer base.

To calculate the churn rate:

(1) Select a certain time frame
(2) Divide the total number of subscribers lost by the total number of subscribers gained

(3) Multiply the result to get the churn rate.[24]

b. Revenue Per User (RPU)

Keeping track of user growth help to determine whether marketing efforts are working or not. RPU, or revenue per user, is a metric used to assess a program's or service's capacity to generate income at the level of a specific consumer. RPU is also sometimes referred to as revenue per unit. This metric's advantage is that it helps to comprehend price structure and consumer base growth trends.

To calculate your RPU: = total customers/total revenue. [24]

c. Active Users

Knowing how many active users you have can help you focus your marketing efforts on those most likely to convert into paying customers. The active user's measure keeps track of how many people interact with a website or service over time.

To determine your active users, you must

(1) identify your criteria for an active user.

(2) Choose the time frame that interests you to study (e.g., day, week, month).

(3) Gather information, then add the total number of distinct users who fit your active user criterion for each time period.

7.4.2 Monitoring and Evaluation (M&E) Framework

Introduction

The integration of science and technology, improvement in relationship between science and technology, the appearance of industries based on science, and the use of science as a means to generate competitive advantages, are some of the reasons to justify collaboration and cooperation between research organizations, industry and the universities.

As an important part of the ecosystem of innovation, knowledge transfer from research institutions and university to industry have great economic and social impacts. Governments and research agencies are seeking ways to evaluate the results of interactions among research institutions, universities and industries. Different approaches to knowledge transfer measurement have been developed around the world.

Licenses

One of the ways to evaluate the performance knowledge transfer is the use of survey of licenses, which gathers information about the performance of technology licensing in the R-U institutions in Ghana. Indicators for measuring licensing is as below:

- Number of licenses
- Income generated from licenses
- Number of products that arose from licenses
- Number of invention disclosures
- Number of complete standard patent applications
- Number of patents granted
- Value of copyright licenses
- Long term relationships created following licensing

Contract Research

Indicators for measuring contract research success are as below:

- Number and value/income of contracts
- Number of products that arose from contracts
- Percent of income relative to total research income
- Length of client relationship
- Number of academic papers published in journals and presented in conferences
- Number of contract research projects which led to other flow-on knowledge transfer activities such as collaborative research,

licensing, and industry sponsored conferences

Spin-off Companies

Spin-off or start-up companies are new companies that commercialize a university technology research result through a license agreement. It often involves a new high-risk research area. This company that is a spin-off from university research programs will also have a formal linkage with the university in terms of facilities sharing and hiring of graduate students. Indicators for measuring success of Spin-off companies are as below:

- Number of spin-offs formed
- Value of revenue generated by the spin-off
- Value of external investment raised
- Flotation/exit value

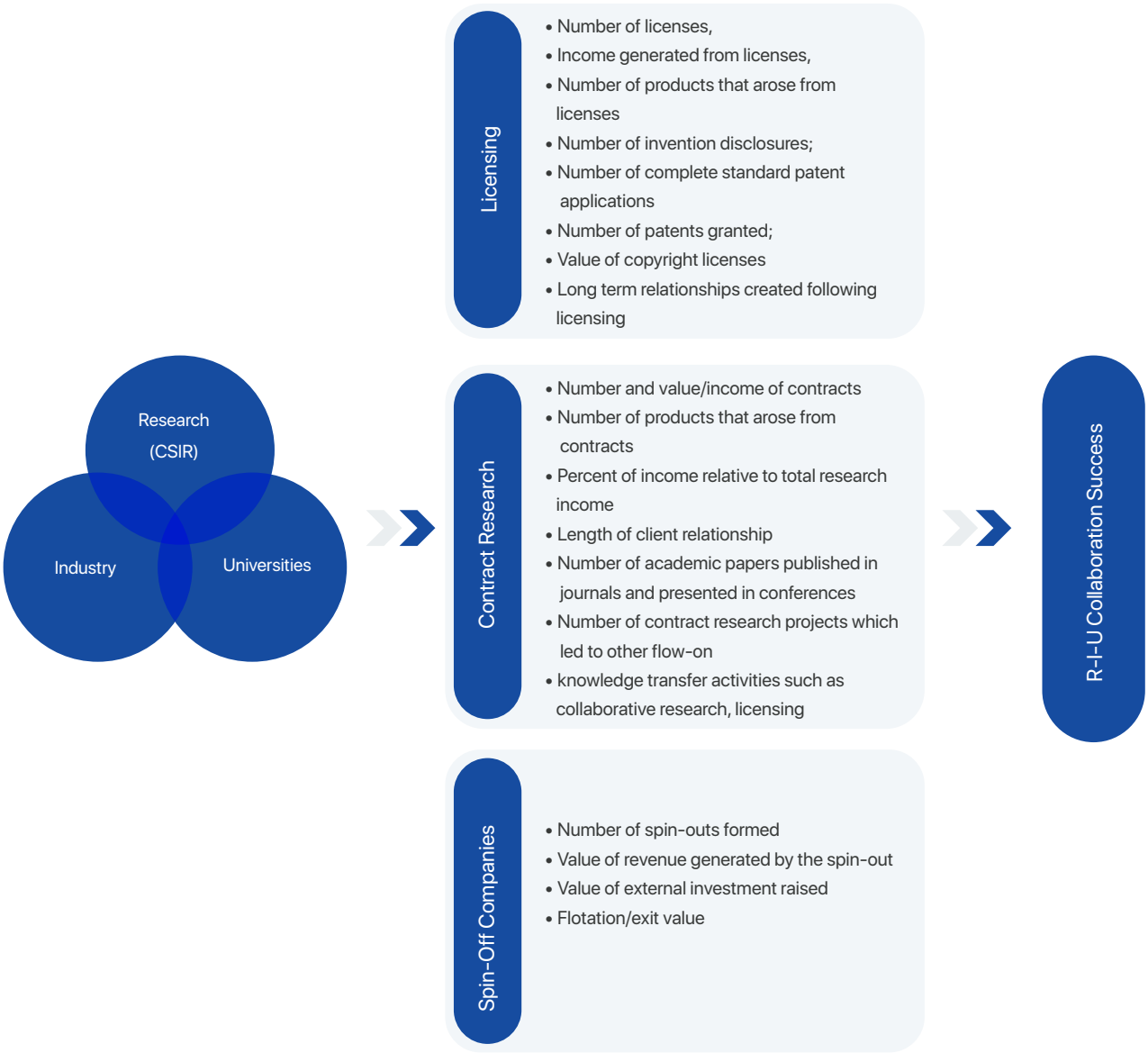


Fig. 13. Research-Industry-University Collaboration Evaluation Framework

Chapter 8

Conclusion and Recommendations

8.1 Conclusion

Key performance indicators (KPIs) help an organization define and measure progress toward organizational goals. KPIs are quantifiable measurements to examine the improvement in performing an innovation implementing activity that is critical to the success of a business. Key performance indicators are financial and non financial indicators that organizations use in order to estimate and fortify how successful they are, aiming previously established long lasting goals. Appropriate selection of indicators that will be used for measuring is of a greatest importance. Process organization of business is necessary to be constituted in order to realize such effective and efficient system or performance measuring via KPI. Process organization also implies customer orientation and necessary flexibility in nowadays condition of global competition,[24]

KPI tells you where performance has been in the past, where it is now, and perhaps more useful, where performance is likely to be in the future.[25]

Innovation adopters often assume that investments in innovation will lead to productivity improvements. However, investment in innovation does not guarantee the effective implementation. Previous research has often shown that adopted innovations (e.g. Lean production, Customer Relation Management (CRM), Enterprise Resource Planning (ERP), and Rapid Prototyping) fail to successfully complete the implementation phase and perceive the improvements. Previous study has indicated that the implementation effort must be monitored and diagnosed. This is essential because it enables individuals and groups to assess where they stand in comparison to their competitors. In addition, assessing innovation performance provides the opportunity of recognising problems and weaknesses and taking corrective action before these problems escalate.[26] Moreover, assessing innovation performance enables organisation claiming their implementation effectiveness accurately. As a result, organisation, perhaps, has been growing and productive because of the innovation, but traditional measurements have failed to capture that growth.

Ghana has since 2018 been thinking of developing its sciences, technologies and innovations to move the country beyond Aid. In conceptualizing the socio-economic development of Ghana, some inputs that must also be in mind include but not limited to the following:

- Looking within
- Local resource mobilization
- Self-sufficiency
- Making good use of resources
- Adding value to our local resources

In summary there must be operationalization of the concept to bring sufficiency of water, food, energy, employment, sanitation, health, etc. to the citizens. Our Research Institutions, the Universities with the local Industries must be able to contribute towards Government's industrialization drive and support Government initiatives such as the one District, one Factory, Planting for Food and Jobs, and one Village one Dam.

The thirteen (13) research institutes of the CSIR, the Ghana Atomic Energy Commission and the science-based universities have major role to play in driving Ghana's socio-economic

development agenda. To able to succeed with these the above institutions must contribute towards giving true meaning to this document and must target the following:

- Encouraging policies that promote the research efforts of the Science community
- Protecting the local industry
- Introducing local technologies that facilitate job creation and address challenges and constraints of industry
- Building the capacity of the Science community to position the country to sustain her activities in the absence of aid or donor support
- Cutting back on imports and building the capacity for local production

Focus of Ghana's development must therefore be geared towards key areas of energy, sanitation, job creation, health, services, food security and value addition, and environment (forestry and soil).

The Committee to be set up to steer the affairs of the R-I-U collaboration must have a five-year Strategic Plan based on the key area identified above. To drive the research-industry-universities agenda,

1. Each of the party involved in the R-I-U must have a situational analysis of the key areas.
2. Consider the strong points and capabilities of each institution that have the potential to advance Ghana's socio-economic development
3. Present projections to Government based on the capabilities of the research institutions and the universities indicating the quantum of drastic reduction in imports to save the country foreign exchange, while creating jobs.
4. Recognize job creation avenues arising from churned out
5. Build the capacity required to realize Ghana's socio-economic development agenda i.e. engineers, technologists, etc.

8.2 Recommendations

- Need for national leadership commitment to implement recommendations in the blueprint
- Identify priority initiatives or projects in the blueprint for the short-term (1-3 years) and long-term (beyond 3 years) implementation.
- Emphasis must be placed on Intellectual Property rights and protection.
- Conduct stakeholder and user forum to validate the priorities
- Publish and distribute the blueprint to relevant stakeholders
- Government to be committed to funding research consistent with allocation of 1% of GDP for research and development.
- There should be periodic interaction of R-I-U community with members of the Economic Management Team for updates on the state of natural resources (land, soil, water, biodiversity, etc.) and other topical issues such as flooding, sanitation and food security.
- Successful research institution-industry collaboration should support the mission of each partner. Any effort in conflict with the mission of either partner will ultimately fail.
- Institutional practices and national resources should focus on fostering appropriate long-term partnerships between research institutions and industry.
- Research institutions and industry should focus on the benefits to each party that will result from collaborations by streamlining negotiations to ensure timely conduct of the

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Appendices

Appendix I

SWOT Analysis of Ghana's System of Innovation

Strengths	Weakness
• Political stability, openness and improved democratic governance • Good macro-economic conditions and performance • Existence of R&D institutions including the CSIR • Existence of several technology support and regulatoryagencies • Bilateral FDI agreements increasing and country participates in regional and international programs • Existence of science and engineering faculties in the public universities; and the ten Technical Universities in Ghana. • Existence of vibrant financial institutions, particularly commercial and development banks • Private sector is growing: increasing number of small and medium scale enterprises; and presence of a good number of foreign companies in mining, agriculture and ICTs • Existence of MESTI, Ministry of Trade and Industry, Private Sector Development and President's Special Initiatives; Ministry of Communication. • Existence of a new National STI Policy. • Youthful Population • Existence of a national science academy and Science based Professional Associations. • Existence of various industry associations and Non- Governmental Organisations. • Existence of indigenous STI knowledge and	• Political parties and parliament do not give adequate attention to science, technology and innovation issues in their practices and policies. • Economy relies on narrow range of traditional exports • R&D institutes under-resourced • Absence of specific budgets dedicated to institutional strengthening • Technology support and regulatory agencies not adequately resourced and linked to R&D institutes. • Lack of strategy and institutional leadership to use bilateral, regional and international cooperation to link up to national systems abroad for purposes of learning and technology prospecting. • Science and technology faculties and the Technical universities are under-resourced; and declining enrollment in science and engineering courses. • Financial institutions are not strategically involved in or linked to R&D and technology development programmes. • Poor links between private companies and public R&D institutions; and limited in-house • R&D and innovation activities in private sector. • Poor coordination among and between ministries; weak policy analysis capacity • Inadequate policy coherence • Low STI culture and reducing interest of the youth in STI Sector.

technology that can be mobilised to help implement an STI agenda • Existence of a pool of unemployed university science graduates who can be engaged to implement an STI agenda. • Existence of a vibrant telecommunications and mass media industry. • Government's efforts to promote private sector development, and recognition by government to encourage commercial use of R&D. • Increasing recognition by government of the need to promote venture capital, R&D in enterprises; and the new Science and Technology Endowment Fund. • Education and training system being reformed to put emphasis on science and engineering; and a new science and technology education policy adopted.	• No budget dedicated to science, technology and innovation policy programmes. • Lack of strong collaboration in the research-industry-universities ecosystems. • Weak institutional leadership of MESTI and lack of deliberate executive or cabinet champion for science and innovation policy. • No budgets dedicated to science and engineering training; science, technology and innovation policy programmes; and institutional strengthening • No clear strategy and institutional leadership to improve infrastructure for R&D and engineering; and to build or improve the R&D institutes. • Lack of institutional leadership to stimulate interest and promote engagement of financial institutions in R&D and technological innovation. • Poor physical infrastructure, particularly costly and unreliable electricity.
Opportunities	**Threats**
• Potential of peer influence and review through the African Union, APRM and NEPAD; and potential to strengthen Parliamentary Committee on Environment and Science. • Increasing FDI inflows: President's Special Initiatives (PSI) good basis for economic diversification. • Increasing ODA: Newly established Science and Technology Endowment Fund. • Initiatives such as NEPAD, AU and CAAST-Net focusing on Ghana; and improving conditions for FDI and technology cooperation. • STI skills and knowledge of Ghanaians in the Diaspora.	• Global economic recession and financial crisis. • Rapid global technological changes making it difficult to keep up to date with global STI innovations • Brain Drain of STI Experts • Dependence on external financial support for R&D making it difficult to pursue an effective national STI agenda • Increasing knowledge and technological gap between developing and developed countries threatens country's ability to be competitive as a nation.

Source: MESTI, 2011; UNCTAD, 2011

Appendix II

Prioritization of Opportunities that give Highest Competitive Advantage

Opportunity	Action Needed	Identified Appropriate Strategic Thrust
Potential of peer influence and review through the African Union, APRM and NEPAD; and potential to strengthen Parliamentary Committee on Environment and Science.	• Actively engage the Development Partners • Proactive engagement with industry	Improve Visibility of the STI Ecosystem
Increasing FDI inflows: President's Special Initiatives (PSI) good basis for economic diversification.	• Develop demand-driven technologies	Industry Driven R&D and Technological Innovation.
STI skills and knowledge of Ghanaians in the Diaspora	• Increase Visibility of technologies developed in Ghana and effectively engage the Ghanaians in the Diaspora. • Active and regular Media and Stakeholder engagement	Improve Visibility of the STI Ecosystem
Initiatives such as NEPAD, AU and CAAST-Net focusing on Ghana; and improving conditions for FDI and technology cooperation.	• Strengthen IPR System and use it to aggressively to promote uptake of Technologies and Services	Financial Resource Mobilisation
Increasing ODA: Newly established Science and Technology Endowment Fund.	• Strengthen IPR System and use it to aggressively to promote uptake of Technologies and Services	Financial Resource Mobilisation

Prioritization of Strengths that give Highest Competitive Advantage

Strength	Action Needed	Identified Appropriate Strategic Thrust
Existence of R&D institutions including then CSIR	• Develop demand driven economically viable technologies for the industry and service sector • Publish scientific papers in high impact journals	Industry Driven R&D and Technological Innovation
Existence of a pool of unemployed university science graduates who can be engaged to implement an STI agenda.	• Effectively attach them to the already established Scientific institutions to develop their skills ready to feed industry.	STI Ecosystem Performance Improvement

Increasing recognition by government of the need to promote venture capital, R&D in enterprises; and the new Science and Technology Endowment Fund.	• Operationalise and intensify IPR Policy	Financial Resource Mobilisation
Existence of indigenous STI knowledge and technology that can be mobilised to help implement an STI agenda	• Patent all marketable technologies developed	Financial Resource Mobilisation

Prioritization of Strengths that give Highest Competitive Advantage

Weaknesses	Action Needed	Identified Appropriate Strategic Thrust
Poor links between private companies and public R&D institutions; and limited in-house R&D and innovation activities in private sector.	• Increase visibility through effective stakeholder management	Improve Visibility of the STI Ecosystem
Lack of strategy and institutional leadership to use bilateral, regional and international cooperation to link up to national systems abroad for purposes of learning and technology prospecting.	• Explore causes of poor staff attitude and resolve issues. • Improve collaboration in the research-industry-universities ecosystems • Collaborate with the International Bodies	STI Ecosystem Performance Improvement
No clear strategy and institutional leadership to improve infrastructure for R&D and engineering; and to build or improve the R&D institutes.	• Clear strategy and institutional leadership to improve infrastructure for RD&I; and to build and improve RD&I institutions. • Commercialise technologies developed through: effective IPR policy operationalisation and piloting of technologies.	Financial Resource Mobilisation

Appendix III

Examples of high-yielding varieties of crops developed and released to farmers by the CSIR

Research Output	Social Impact	Gains/Savings (Annually)
Seventeen improved varieties of maize have been released and adopted by farmers.	These varieties constitute 50 - 70% of the 262,987ha grown in Northern Ghana. They yield 100% more than the 1,950 kg/ha obtained from the old varieties. Sufficient food is available to adequately feed the increasing population in the mandate area.	Gain = GH₵7,179,545,100.00 (assuming only 100% increase in yield), (262,987 ha x 1.95 t/ha x GH₵14,000/t = GH₵7,179,545,100.00)
Six improved varieties of sorghum have been released and adopted by farmers.	These varieties constitute 30% or 88,500 ha of the 295,000ha grown in Northern Ghana. They yield 100 to 400% more than the 700 kg/ha obtained from the landraces. Sufficient food is available to adequately feed the increasing population in the mandate area. Kapaala can also replace barley malt in the brewing industry.	Gain = GH₵2,478,000.00 (assuming only 100% increase in yield), (88,500 ha x 0.7 t/ha x ₵400,000/t = GH₵2,478,000.00)
Five improved varieties of rice developed and released to farmers	Almost all the 80,000ha grown every year by farmers in northern Ghana was recommended by the CSIR-SARI. The newly recommended improved varieties yield between 100% (2 t/ha) and 600% (6 t/ha) over the local variety, depending on the production ecology. Currently about 70% or 56,000 ha of rice cultivated in northern Ghana are varieties released.	Assuming 100% increase in yield. Gain = GH₵4,032,000.00 (56,000 ha x 2 t/ha x ₵360,000/t.
Seven improved varieties of groundnuts released and adopted by farmers. These include i) Mani pinta ii) Shi tao chi (Chinese) iii) F-mix iv) Zinkarzie v) Edorpo-Munikpa vi) Kpanielli and vii) Nkatiesari.	It is estimated that of the 160,000 ha of groundnuts grown in northern Ghana 90% or 144,000 ha consist of improved varieties recommended by CSIR-SARI. The new varieties give yield increase of 0.3 t/ha more than the earlier recommended varieties.	Gain = GH₵ 2,863,106.00 (0.3 t/ha x 144,000 ha x ₵662,756/t = ₵28,631,059,200)

CSIR-SARI released improved varieties of cowpeas which are resistant to diseases, pests and drought, and are early maturing and can therefore be grown twice a year. These include Valenga, Bengpla, Val x Be, Marfo-tuya and Apaagbala.	Currently, about 100,000 ha of groundnuts are cultivated annually in northern Ghana. The improved varieties yield more than thrice the 100 kg/ha obtained by those who still cultivate the local varieties. So far adoption rate is about 50%.	Assuming only 100% yield increase, Gain = ¢5 billion (0.5 x 100,000 ha x 200 kg/ha x ¢500/kg = GH¢ 500,000.00)
CSIR-SARI has released five improved soybean varieties to farmers. These are Jenguma, Quarshie, Suong-Pungun, Songda and Afayak.	Currently there are 98,246 ha under cultivation. Farmers obtain a yield of 1,360 kg/ha. However, this value can go up to 1.8-2.8 t/ha. Aside the cash returns soybean is used in the manufacture of weaning foods. It also provides good quality oil for food, and the cake after oil extraction is also employed in the animal feed industry.	GH¢280,590,576,000.00 (98,246 ha x 1,360 kg/ha x GH¢2,100/t) = GH¢280,590,576,000.00

Some research outputs to control pests in storage, their social impact and potential savings to the country

Research Output	Social Impact	Gains/Savings (Annually)
IPM for the control of cowpea pests. Management strategies recommended include i) use of resistant varieties ii) appropriate planting dates and minimum insecticide use iii) role of beneficial insects iv) use of neem seed extract	The technology reduces reliance on synthetic insecticides, and as a result reduces cost and health hazard. Insecticide recommendations have been reduced from 5 to 2. It is now practiced by 20% of farms.	Savings: ¢1.5 billion
Pest scouting before spraying in cotton production	Reduces spraying from 7 to 4 without significant yield loss. It has a great potential for reducing health hazard	Savings: over GH¢670,000.00 if total cotton crop of 50,000 ha would adopt the technology
Cowpea-cotton intercrop. Cowpea benefit from routine insect pest control on cotton An additional yield of 300 kg/ha of cowpea is obtained without any adverse effect on cotton yield.	The cowpea intercrop enhances the soil fertility for a subsequent crop and provides additional income to farmers outside of that derived from the main cotton crop	GH¢750.00 (Current gain) If universally adopted an additional gain of ¢7.5 billion would be achieved

Some postharvest technologies and their impact

Postharvest Technologies	Description Of Technologies	Impact
Design and construction of greenhouse driers to dry hot peppers	The pepper variety Capsicum chinense cultivated in the district is not amenable to open sun drying, hence there is always a glut on the market, and farmers get very little from their toil. Three greenhouse driers were constructed in three communities within the district. The driers dried a batch of 8 maxi bags of pepper between 9 and 14 days, depending on weather conditions. Ratio of shrinkage of the dried pepper to the fresh one was 1:3	In all 39.5 bags of dried pepper was obtained A bag of dried pepper sells at ¢400,000 now. What should have been sold at GH¢355.50 (i.e. 39.5 x 3 x ¢30,000) will now sell at GH¢1,580.00 a difference of GH¢1,224.50. The drier is expected to last for at least 10 years if maintained well.
Blanching of hot peppers employing the solar blanching technology	The technology involves spreading the sorted pepper over a black polythene sheet in the open sun and covering it with a transparent one for between 2 and 3 hours, depending on weather conditions. The heat generated between the plastic sheets blanches the pepper, destroying all enzymes and most microbes on and in the produce. To test that the produce it totally blanched a drop of 0.1% hydrogen peroxide is dropped to the freshly cut surface. Lack of gas bubbles is an indication that the produce is adequately blanched.	About 140 farmers and pepper processors within seven communities in the Tolon/ Kumbungu district have been trained in this technology. In addition the communities trained were provided with enough materials (black and transparent plastic sheets) to enable them practice the technology on their own

Impact of promoting nursery technologies and plantation activities

Impact	Significance of Impact	Remarks
Contribution toward food security	Very positive	Wild foods and spices, snails, mushrooms and wildlife Improved integrated tree-crop systems
Contribution toward timber industry	Very positive	Increase in numbers of timber trees. The introduction of lesser known species to reduce pressure on endangered indigenous species
Biodiversity	Very positive	Rehabilitation and reclamation of degraded forests and mined sites and introducing a variety of plant and animal life back into degraded landscape Protection of watersheds and ensuring that Ghana has enough water for domestic and industrial consumption

Carbon sequestration and climate regulation	Very positive	Trees in carbon capture and the long-term storage of atmospheric carbon dioxide
Soil Conservation	Very positive	Litter decomposition and nutrient recycling will improve soil status

Some processing technologies of the CSIR that can contribute to Ghana's development

Technology	Situational Analysis	Socio-economic Development
Mushroom • *The CSIR-FRI trains people on spawn multiplication* • *Cropping of oyster mushroom, domo and ganoderma*	The CSIR-FRI has trained about 20 people both local and international (Togo, Nigeria, and Sierra Leone) The CSIR-FRI has trained about 4000 farmers to produce fresh mushrooms for both local and foreign markets in other to meet all year round demand of about 2,500 spawn bottles.	There is a high demand of about 4000 mushroom spawns a month, thus we need to expand our facility to meet such demands.
• *High Quality cassava flour, composite flour of roots and tubers (potato, yam, cocoyam).*	Trained about 20,000 farmers to reduce post-harvest losses by value addition into flour, gari, tapioca, cassava chips among others that can last for about 2 years.	The CSIR-FRI aims to train more farmers to engage in this technology
• *Fish work From Chorkor- Ahotor*	Developed Ahotor oven which can now smoke large quantities of fish with lesser fuel input, more hygienic and produce more safe fish products, reduce post-harvest losses and lower Polyaromatic Hydrocarbon (PAH).	Ministry of fisheries and fish processes along the coast has adopted this new technology to curb post-harvest losses, reduce use of fire wood during bumper harvest. Ministry of fisheries is planning on disseminating about 2000 ovens along the coast and training entrepreneurs to make snacks form trimmers that would have gone waste.
Fruit Processing (Fruit Drying Oven).	Trained entrepreneurs about 2000 on various forms of fruits processing juice production, concentrates (marmalade, jams). Developed fruit drying oven and trained 50 entrepreneurs who are drying mango, banana	This activity will be doubled on the fruits processing to curb post-harvest losses. Dried fruits to be incorporated into the school feeding programs.

Vegetables and spices (solar and mechanical drying and mill with hammer mill)	Developing drying systems for vegetables and mechanical dryers. Spices using solar and mechanical dryers. Trained about 1500 entrepreneurs who are packaging and distributing on both local and international markets	Train more entrepreneurs on safe and standardized products for non-traditional exports
Frozen yam Technology	Trained about 60 entrepreneurs to prepare all the types of yams including water yam which is used less into ampesi chunks and yam chips	The CSIR-FRI expects to reduce losses of exported yams to foreign destinations when value is added to enable non export commodities like yams to be exported. FAO reports that in 2014 there was postharvest loss of 60% in yams.
Rice: Rice par boiling to reduce breakages resulting in 96% of whole grains after processing. (Rice par-boil vessel)	Trained about 3000 farmers who are using the par boiling technology to improve the quality of rice and maintain nutritional content.	Increase training of more rice farmers to improve the quality of rice (long grain rice) with more nutritional qualities to improve their sales and for school feeding programs. Also, aid districts that produce rice.
Ethanol and glucose syrup production system to be produced from local raw materials like cassava etc.	Trained about 5 entrepreneurs and 2 of them are producing now in small quantities	To train more farmers and intermediary entrepreneurs to convert raw materials to reduce import of glucose and ethanol for the pharmaceutical industries
Fabrication of food processing equipment **Dryer** (solar, gas cabinet and mechanical dryer) **Mill** (hammer, attrition and choloid mill) **Press** (manual press, hydraulic press and mechanical press) **Others**: graters, sifters, dehaulers, slicers, graders	We have trained about 90 entrepreneurs, individuals and groups and have set up various equipment in Ghana	To train more individuals and farmers to acquire this appropriate technology equipment into the one district one factory facilities to reduce postharvest losses.

Job Creation from CSIR-BRRI Technologies

CSIR – BRRI Technology	Number of Possible Sites Across The Country	Total Production/ Services Capacity	Annual Revenue GH¢	Number of Employment Opportunities
Pozzolana Cement factories	6	3,000,000 tonnes per annum	Gh¢ 900 m	**15,000** Direct Employment
Clay Brick and Tile factories	120	750,000,000 pieces of burnt bricks	Gh¢ 600 m	**24,000** Direct Employment for the youth
Research, Training, and Project	254	254 consultancy centres in all districts across the nation	Gh¢ 350m	**8,000** Direct Employment for graduates

The Development of CSIR-Industry Collaborative Blueprint And Implementation Framework

Heritors Labs

CSIR-Science and Technology Policy research Institute (CSIR-STEPRI)

UKaid

RISA Research and Innovation Systems for Africa