

NATIONAL COMMISSION FOR SCIENCE AND TECHNOLOGY (MALAWI)



NATIONAL RESEARCH AGENDA IN ENERGY, INDUSTRY AND ENGINEERING (2017 – 2022)

'A nation with scientifically and technologically led sustainable growth and development'

NATIONAL COMMISSION FOR SCIENCE AND TECHNOLOGY (MALAWI)

NATIONAL RESEARCH AGENDA IN ENERGY, INDUSTRY AND ENGINEERING (2017 – 2022)

NCST Secretariat
Lingadzi House
Private Bag B303
City Centre
Lilongwe 3
Malawi

Tel: + 265 1 771 550/ 774 189/ 774 869

Fax: + 265 1 772 431

E-Mail: directorgeneral@ncst.mw

Website: www.ncstmw.org

February 2017

CONTENTS

FOREWARD	V
ACKNOWLEDGEMENTS	VI
ACRONYMS AND ABBREVIATIONS	VII
1 INTRODUCTION AND BACKGROUND INFORMATION	8
1.1 CHALLENGES AFFECTING RESEARCH AND DEVELOPMENT ACTIVITIES	8
1.1.1 <i>Limited Human and Financial Resources</i>	8
1.1.2 <i>Inadequate Infrastructure Capacity</i>	8
1.1.3 <i>Low Knowledge Generation and Research and Development Productivity</i>	9
1.1.4 <i>Limited Institutional Collaboration and Partnerships</i>	9
2 RATIONALE	9
3 POLICY, REGULATORY, AND INSTITUTIONAL FRAMEWORK	9
3.1 THE MALAWI GROWTH AND DEVELOPMENT STRATEGY II (2011 – 2016)	10
3.2 THE ECONOMIC RECOVERY PLAN	13
3.3 THE SCIENCE AND TECHNOLOGY ACT (2003)	13
3.4 NATIONAL SCIENCE AND TECHNOLOGY POLICY (NSTP) (2002)	13
3.5 THE NATIONAL EXPORT STRATEGY (MNES)	14
4 GOAL AND OBJECTIVES	15
5 METHODOLOGY	15
5.1 STAKEHOLDER CONSULTATIONS	15
5.2 REVIEW OF IDENTIFIED R&D AREAS AND FORMULATION OF RESEARCH QUESTIONS	15
5.3 PRIORITISATION OF R&D THEMATIC AREAS AND ACTIVITIES	16
5.4 DRAFTING OF THE RESEARCH AGENDA	16
5.5 STAKEHOLDERS CONSULTATION	16
6 PRIORITY AREAS OF RESEARCH AND DEVELOPMENT IN ENERGY, INDUSTRY AND ENGINEERING	16
6.1 CONSTRUCTION	ERROR! BOOKMARK NOT DEFINED.
6.1.1 <i>Objective</i>	Error! Bookmark not defined.
6.1.2 <i>Prioritized areas of research and development</i>	17
6.2 TRANSPORT AND TRANSPORT INFRASTRUCTURE	17
6.2.1 <i>Objective</i>	Error! Bookmark not defined.
6.2.2 <i>Prioritized areas of research and development</i>	18
6.3 AGRO-PROCESSING	ERROR! BOOKMARK NOT DEFINED.
6.3.1 <i>Objective</i>	Error! Bookmark not defined.
6.3.2 <i>Prioritized areas of research and development</i>	18
6.4 MANUFACTURING	ERROR! BOOKMARK NOT DEFINED.
6.4.1 <i>Objectives</i>	Error! Bookmark not defined.
6.4.2 <i>Prioritized areas of research and development</i>	19
6.5 MINING	ERROR! BOOKMARK NOT DEFINED.
6.5.1 <i>Objective</i>	Error! Bookmark not defined.
6.5.2 <i>Prioritized areas of research and development</i>	Error! Bookmark not defined.
6.6 ENERGY	20
6.6.1 <i>Objective</i>	Error! Bookmark not defined.

6.6.2	<i>Prioritized areas of research and development</i>	20
6.6.2.1	Non Renewable energy	20
6.6.2.2	Renewable energy	20
6.6.2.3	Energy efficiency and conservation	21
6.7	ENVIRONMENT	21
6.7.1	<i>Objective</i>	<i>Error! Bookmark not defined.</i>
6.7.2	<i>Prioritized areas of research and development</i>	<i>Error! Bookmark not defined.</i>
6.8	AGRICULTURE AND IRRIGATION.....	ERROR! BOOKMARK NOT DEFINED.
6.8.1	<i>Objectives</i>	<i>Error! Bookmark not defined.</i>
6.8.2	<i>Prioritized areas of research and development</i>	<i>Error! Bookmark not defined.</i>
6.9	WATER AND SANITATION.....	ERROR! BOOKMARK NOT DEFINED.
6.9.1	<i>Objective</i>	<i>Error! Bookmark not defined.</i>
6.9.2	<i>Prioritized areas of research and development</i>	<i>Error! Bookmark not defined.</i>
6.10	CLIMATE CHANGE ADAPTATION AND MITIGATION	ERROR! BOOKMARK NOT DEFINED.
6.10.1	<i>Objective</i>	<i>Error! Bookmark not defined.</i>
6.10.2	<i>Prioritized areas of research and development</i>	<i>Error! Bookmark not defined.</i>
6.11	HEALTH	ERROR! BOOKMARK NOT DEFINED.
6.11.1	<i>Objective</i>	<i>Error! Bookmark not defined.</i>
6.11.2	<i>Prioritized areas of research and development</i>	<i>Error! Bookmark not defined.</i>
6.12	INFORMATION AND COMMUNICATION TECHNOLOGY (ICT).....	28
6.12.1	<i>Objectives</i>	<i>Error! Bookmark not defined.</i>
6.12.2	<i>Prioritized areas of research and development</i>	28
6.13	NANOTECHNOLOGY	29
6.13.1	<i>Objectives</i>	<i>Error! Bookmark not defined.</i>
6.13.2	<i>Prioritized areas of research and development</i>	29
7	IMPLEMENTATION STRATEGIES	30
8	FINANCING MECHANISM OF THE RESEARCH AGENDA	30
8.1	RESEARCH GRANTS SCHEME	30
8.2	PUBLIC AND PRIVATE PARTNERSHIPS	30
8.3	OTHER FINANCING MECHANISMS.....	31
9	DISSEMINATION OF RESEARCH AND DEVELOPMENT FINDINGS	31
10	COMMERCIALISATION OF RESEARCH RESULTS	31
11	MONITORING AND EVALUATION OF THE IMPLEMENTATION OF THE RESEARCH AGENDA	32
11.1	CHECKLIST FOR SUBMISSION OF PROJECT PROPOSALS FOR REGISTRATION AND REVIEW	32
11.2	MONITORING AND EVALUATION (M&E) REPORTS.....	32
11.3	PROGRESS AND FINAL REPORTS.....	33
11.4	DATABASE AND DIRECTORY OF RESEARCH AND DEVELOPMENT ACTIVITIES.....	33
11.5	REVIEW OF THE AGENDA.....	33
12	LIST OF SOURCE MATERIALS	34
ANNEX 1: RESEARCH AGENDA IN ENGINEERING, ENERGY AND INDUSTRY – ACTION PLAN		35
ANNEX 2: LIST OF MEMBER ORGANISATIONS FOR THE NATIONAL COMMITTEE ON ENERGY, INDUSTRIAL AND ENGINEERING SCIENCES (NCEIES)		39
ANNEX 3: LIST OF MEMBERS OF THE DRAFTING COMMITTEE		40

FOREWARD

The countries that do not pay careful attention to, and fail to make targeted investments in, science, technology and innovation (ST&I), are those that are socioeconomic laggards of today. It is abundantly clear that those that are in the league of developed nations are the ones that have supported, structured and managed ST&I to gain maximum effect in a competitive world. It is evident from the Malawi Vision 2020 that Malawians have, since the last quarter of the last century been aspiring to have, among other things, “a technologically driven middle-income economy”. That there have been attempts since then by the Government of Malawi (GoM) to create an enabling environment for the translation of this aspiration of having “a technologically driven middle-income economy” into action is evident from its decision to approve a 2002 national science and technology (S&T) policy.

The overall goal of the S&T policy was to nurture and foster the endogenous development and transfer of science and technology (S&T) for socioeconomic development. The GoM's determination to ensure that S&T were developed and transferred for national development was underscored by the enactment of the Science and Technology Act (2003) and the creation in 2009 of the National Commission for Science and Technology (NCST) both of which were aimed at providing a legal and institutional framework to support Government's efforts to develop and promote utilisation of S&T for addressing macroeconomic and social challenges consistent with its long term development strategy, as outlined in Vision 2020, of achieving, among other things, a transformation to “a technologically driven middle-income economy”. In addition to these measures, S&T variables have also been included in the MGDS II (2011-2016), an overarching development strategy for Malawi, as one of the priority areas. It is, however, observed that S&T variables have not been able to be so strategically integrated that they are able to create technology platforms for enhanced sustainable productivity growth.

One of the factors contributing to this observation is the failure to mainstream science, technology and innovation (ST&I) in all sectors of the economy and to create an environment that is conducive to effective utilisation of available ST&I capacities and capabilities in programmes that respond to national needs. One of the elements of such an environment is the inadequate funding for research and experimental development (R&D) which is far below the 1 per cent of GDP envisaged in the Malawi Vision 2020. Another factor contributing to the significant impact made by ST&I on efforts to achieve national growth and development targets is the failure to have the limited available resources invested in identified priority areas whose investigations could have led to availability of ST&I deemed necessary for the enhancement of productivity growth. It is for this reason that the GoM has developed this National Research Agenda In Energy, Industry And Engineering as a policy document that will guide R&D activities

in the identified priorities areas in energy, industry and engineering during the period from 2017 to 2022. It is, however, recognised that the success of this Agenda in achieving its objectives has immense human, financial and capital implications.

ACKNOWLEDGEMENTS

The development of the Research Agenda in Energy, Industry and Engineering was a consultative process coordinated by the National Commission for Science and Technology (NCST) through the National Committee on Energy, Industrial and Engineering Sciences (NCEIES). The composition of NCEIES is shown in Annex 1. The NCST would therefore, like to acknowledge the efforts and contributions of all stakeholders, so numerous to mention, towards the development of this Agenda. To all of them go profound thanks of the NCST for a job well done. The NCST is also indebted to members of drafting committee (Annex 2.) whose contributions included the analysis of data, prioritisation of the research areas, and drafting this Research Agenda.

ACRONYMS AND ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
EHP	Essential Health Package
GoM	Government of Malawi
HIV	Human Immunodeficiency Virus
ICT	Information and Communication Technology
ERP	Economic Recovery Plan
MGDS	Malawi Growth and Development Strategy
MGDS II	Malawi Growth and Development Strategy II
NES	National Export Strategy
M&E	Monitoring and Evaluation
NCEIES	National Committee on Energy, Industrial and Engineering Sciences
NCST	National Commission for Science and Technology
NGOs	Non Governmental Organisations
NRAEIE	National Research Agenda in Energy, Industry and Engineering
NSTP	National Science and Technology Policy
R&D	Research and Development

1 INTRODUCTION AND BACKGROUND INFORMATION

In Malawi, research and development (R&D) in the fields of energy, industry, engineering and related areas is principally carried out by public R&D institutions which are mainly funded by government. These institutions include University of Malawi's The Polytechnic and Chancellor College, Mzuzu University, Lilongwe University of Agriculture and Natural Resources, Malawi University of Science and Technology, Malawi Bureau of Standards, and the Department of Agriculture Research Services specifically Chitedze Agriculture Research Station.

- **Challenges Affecting Research and Development Activities**

R&D activities in Malawi are however faced with a number of challenges. These challenges have resulted into low levels of R&D output and have adversely affected the socio-economic development of the country. The main challenges affecting R&D activities in Energy, Industry and Engineering include:

1.1 Limited Human and Financial Resources

Most of the R&D institutions working in the areas of energy, industry and engineering have inadequate numbers of qualified staff to carry out research as revealed by the high rate of vacant positions which exist in these institutions. Other challenges faced by these institutions include inadequate financial resources for research and training, brain drain of qualified staff and in some cases lack of managements' commitment to promote research and development.

1.2 Inadequate Infrastructure Capacity

Most R&D institutions do not have appropriate facilities including laboratories and workshops for carrying out research and development. Where laboratories and workshops exist; they are in poor condition, lack critical research equipment or are old and obsolete. R&D activities require state of the art equipment which is often very expensive and therefore becomes difficult for these institutions to acquire due to limited financial resources.

Information and Communication Technologies (ICTs) such as computers are available in most R&D institutions, however they are inadequate. In addition these institutions have poor internet and intranet connectivity, lack important technical software exacerbated by lack of proper information archiving and sharing within and outside the institutions. Knowledge acquisition is also restricted due to limited access to renowned databases of technical and academic research papers. Consequently researchers are unable to access relevant and up-to-date information on particular areas or subjects.

1..3 Low Knowledge Generation and Research and Development Productivity

Knowledge generation and research productivity, technology development and commercialisation of research results in the Energy, Industry and Engineering sectors are very low. This is mainly due to lack of collaboration amongst institutions; inadequate dissemination forums for research results; lack of mechanisms to commercialise research results; lack of systems to incentivize researchers and research institutions to share research findings and possible research ideas; and lack of adequate laboratory space, equipment and software. As a result, relevant information is not readily available to stakeholders.

1..4 Limited Institutional Collaboration and Partnerships

Collaboration and partnerships between the private sector and government, donor community and researchers or research institutions is very limited to facilitate proper implementation of research projects both locally and internationally. This has resulted into different R&D institutions being involved in similar research and development activities. Duplication of efforts and conducting of research on obvious issues have a negative impact on the utilisation of scarce resources, In addition research and development activities undertaken are not necessarily demand driven.

2 RATIONALE

This Research Agenda represents nationally set and agreed priorities in energy, industry and engineering in which research efforts for Malawi will be concentrated over the next five years. The development of R&D priority areas will therefore ensure that;

- Human resource training and development; and infrastructure capacity development efforts in R&D in energy, industry and engineering are geared towards addressing the priority areas;
- Research and development activities are commissioned, conducted and funded with alignment to national priorities;
- Links between research, action and policy are reinforced;
- R&D institutions/ researchers are made aware of the R&D needs of the country; therefore concentrating their efforts in addressing these needs; and
- Collaboration and partnerships between the private sector, government and donor community and researchers or research institutions are enhanced for the implementation of research projects both locally and internationally.

3 POLICY, REGULATORY, AND INSTITUTIONAL FRAMEWORK

The identified R&D priority areas were those that were aligned to Malawi Vision 2020, National Science and Technology Policy (2002), the Science and Technology Act (2003), and the

MGDS II (2011 - 2016). The views of relevant stakeholders who had been consulted were also taken into account.

3.1 Malawi Vision 2020

Malawi Vision 2020 is a long-term framework based on a long-term multi-sectoral approach, which “provides background information and justification for the aspirations of the people of Malawi”. One of the aspirations of Malawians envisaged in the Vision is to have “a science and technology (S&T)-driven economy, characterized by improved science and technology education, training and culture; increased commercialization of research and development (R&D); adaptation and promotion of new and emerging technologies; promotion of environmentally-sound technologies; existence of effective science and technology (S&T); and increased implementation and use of information technology”. With only about three years of the life of the Vision remaining, and since the life of the Vision has only about three years remaining, a brief indication of the six priority areas that had been identified as needing to be attended to in order for Malawi to have “a science and technology (S&T)-driven economy” may serve to inform why this aspiration has not been translated into reality.

The six priority areas that have been identified are (i) Improving Science and Technology Education, Training and Culture, (ii) Promotion and Commercialisation of Research and Development, (iii) Promoting the Transfer and Adaptation of New and Emerging Technologies, (iv) Promoting Environmentally-Sound Technologies, (v) Achieving Effective Science and Technology and (vi) Promoting Use of Information Technology. Regarding the first priority area, it was recognised that the capacity of education and training institutions to meet the requirements of the country's technological development was then low and that the challenges that needed to be addressed in improving “science and technology education, training and culture” included: (i) reviewing school curricula, (ii) promoting and encouraging skills training and development, and (iii) developing science and technology culture. Central among the strategic options that had been recommended in order to meet these challenges were the following:

- strengthening S&T education;
- introducing specialization in the teaching of science subjects;
- formalizing science curriculum in primary schools as a building block and prerequisite for secondary school science; redesigning curriculum so that physics, chemistry, and biology are taught separately;
- introducing and promoting computer studies;
- strengthening the teaching of technical subjects and emphasizing applied science;

- setting up scholarships for graduate studies in Malawi in priority areas;
- addressing the problem of brain drain from other sectors; and
- introducing S&T achievement awards.

For the second priority area, it was observed that the then number of R&D personnel was “unacceptably low” and investment in R&D to be also low. The challenge is to promote R&D both by the public and the private sectors. The identified strategic challenges to be addressed included (i) attracting foreign direct investment and promoting technology transfer, (ii) establishing monitoring mechanisms for technology transfer, (iii) building capacity to assimilate technology, and (iv) protecting intellectual property-rights. The strategic options that had been identified to deal with the above challenges included:

- increasing private sector membership in National Research Council of Malawi (NRCM);
- the institutional framework for S&T;
- promoting and accelerating R&D dissemination and commercialisation;
- increasing R&D funding to reach at least 1 per cent of GDP;
- introducing an R&D levy on industry;
- according incentives for R&D activities;
- promoting deliberate import material substitution; and
- building and strengthening S&T institutional infrastructure.

Achieving effective science and technology was identified as a priority area after recognizing that Malawi lacked the following conditions for S&T assimilation and diffusion: (a) well functioning information networks, (b) availability of workers with the skills to assimilate technologies, (c) adequate resources for the introduction of new products and services, (d) conducive cultural practices, and (e) existence of a comprehensive national S&T policy. The strategic challenges that had been identified in order to achieve effective S&T included (i) increasing the number of scientists and technologists, (ii) promoting effective transfer of technology, (iii) periodically evaluating the performance of S&T institutions, (iv) addressing gender issues in S&T, and (v) developing a comprehensive national S&T policy. The strategic options that had been recommended to meet these challenges were:

- reducing the rate of attrition of S&T human resources;
- enhancing gender balance in science and technology-led development;
- expanding and encouraging education and training in science and engineering;
- increasing training of S&T educators at all levels;

- encouraging the establishment of private S&T oriented training institutions;
- reviewing the current S&T policy and developing a more comprehensive national S&T policy;
- establishing capabilities for technology negotiation; and
- periodically evaluating performance of S&T institutions.

The sixth priority area (Promoting Use of Information Technology) was identified after observing that a developing country needed “information technology to achieve development in all spheres of human endeavour” and that “Malawi’s use of information technology is too low to meet this objective”. In order to promote the use of IT, the strategic options recommended included the following:

- reviewing the Telecommunications Act to create an independent licensing body;
- improving investment opportunities in IT;
- removing monopolistic tendencies within IT industry;
- reducing tariffs on imported computers and parts to reduce costs;
- improving access to national and international information;
- introducing computers at early stages of education; and
- according duty-free importation of information technology equipment for use in private and public schools and colleges.

3.2 The Malawi Growth and Development Strategy II (2011 – 2016)

The Malawi Growth and Development Strategy II (MGDS II) is the current overarching development strategy for Malawi. It is an operational medium-term strategy designed to attain Malawi’s Vision 2020. The objective of MGDS II is to continue reducing poverty through sustainable growth and infrastructure development following the successful implementation of the MGDS I between 2006 and 2011. The MGDS II identifies nine key priority areas drawn from six themes with the aim of sustaining and accelerating economic development within a short period of time, and with the available resources. The key priority areas are: Agriculture and Food Security; Transport Infrastructure and the Nsanje Inland Port; Energy, Industrial Development, Mining and Tourism; Education, Science and technology; Public Health, Sanitation, Malaria and HIV and AIDS Management; Integrated Rural development; Greenbelt Irrigation and Water Development; Child Development, Youth Development and Empowerment; and Climate Change, Natural resources and Environmental Management.

3.3 The Economic Recovery Plan

During the first year of the implementation of the MGDS II, Malawi faced a number of macroeconomic challenges which included reduced disposable incomes due to poor tobacco revenues, severe scarcity of foreign exchange, and persistent power disruptions. The severe foreign exchange shortages had a negative impact on imports of strategic commodities including fuel and industrial raw materials. Government, therefore, developed the Economic Recovery Plan in 2012 (ERP) which focused on immediate policy reforms; and short and medium term measures that would bring quick wins to the economy. In the medium term the ERP will ensure that energy generation and supply, transport infrastructure and export diversification are addressed quickly. Tourism, mining, manufacturing, commercial farming, agro-processing and Information Communication Technology (ICT) were identified as the focus areas to assist in generating the desired foreign exchange earnings.

3.4 The Science and Technology Act (2003)

The Science and Technology Act No. 16 of 2003 provides for the advancement of science and technology; the establishment of the National Commission for Science and Technology and the establishment of the Science and Technology Fund amongst others. The S&T Act mandates the National Commission for Science and Technology to:

- (a) Advise Government and other stakeholders on all science and technology matters in order to achieve a science and technology-led development
- (b) Chart out national direction and establish national priorities in science and technology development in relation to socio-economic development needs
- (c) Appraise, review, monitor and evaluate priority research and development programmes, plans and projects of R&D institutions and undertake independently or in collaboration with appropriate person, body or institution surveys and research investigations considered necessary.

3.5 National Science and Technology Policy

The promulgation of the National Science and Technology Policy (NSTP) in 2002 underscores the important role Malawi attaches to the development and application of science and technology in socio-economic development of the country. It also recognises that developed countries maintain their leadership positions in socio-economic development mainly due to their strength in scientific and technological capabilities. Developing countries on the other hand are poor mainly due to low productivity caused largely by the low scientific and technological capabilities. They lack ownership of the factors and means of development; hence they acquiesce to positions advanced by donors and other development partners regarding accumulation of national capabilities. In Malawi, this is manifested by lack of competitiveness owing to the lack of change in the structure of the economy. The National Science and

Technology Policy is consistent with other sectoral policies in advocating for the advancement of Science and technology for the socio-economic development of the country through:

- (a) Ensuring adequate and sustained supplies of energy for continued economic growth and development;
- (b) Shifting the country's economy from predominantly consuming and importing to predominantly producing and exporting; Malawi has been producing and exporting primary commodities, which are of low technology content; what Malawi should shift to is the export of value-added products; i.e., high technology-content products);
- (c) Ensuring that every Malawian has equitable access to basic needs and services at an affordable cost for sustainable development, social and economic welfare, and prosperity of the people of Malawi;
- (d) Facilitating the increase and overall productivity of the agriculture sector through irrigation and mechanisation amongst others;
- (e) Promoting the efficient utilisation and management of natural resources in the context of sustainable development;
- (f) Promoting and developing the construction industry; and
- (g) Providing a coordinated transport environment that fosters a safe and competitive operation of commercially viable, financially sustainable and environmentally friendly transport services and enterprises.

3.6 The National Export Strategy

Over the past 10 years exports have grown at a much slower pace than imports creating an unsustainable structural trade deficit that leaves Malawi vulnerable to aid and foreign exchange shocks. The National Export Strategy (NES) provides a clearly prioritised road map for building Malawi's productive base to generate sufficient exports to match the upward pressure on imports. The NES targets to raise exports as a share of imports from 51.5 per cent in 2010 to 75.7 per cent in 2017 and 93.4 per cent in 2022.

Specifically, the NES seeks to:

- (a) Develop three priority clusters namely oil seed products, sugar cane products and manufacturing and also support existing export clusters (tobacco, mining, tea, tourism, services) in which Malawi can compete and that have strong economic spill-overs, thus allowing for the diversification of exports; and
- (b) Improve the enabling environment for the productive base such that investment growth may increase in the productive sectors (including domestic and foreign direct investment into the production of competitive goods and services for export) and the enabling sectors (or those necessary to address supply-side constraints, such as energy, finance and transport).

4 GOAL AND OBJECTIVES

The overall goal of the National Research Agenda in Energy, Industry and Engineering is to guide researchers, technologists, policy makers, program implementers, academic institutions, development partners, investors and other stakeholders on R&D priority areas for Malawi in construction, transport, energy, mining, agro-processing, manufacturing, environment, climate change adaptation and mitigation, health and ICT in line with the national development agenda.

The specific objectives of this Research Agenda are to:

- 4.1 Promote the conduct of research in Energy, Industry and Engineering that is responsive to the socio-economical development of the country;
- 4.2 Promote multidisciplinary and collaborative research;
- 4.3 Facilitate the mobilization of resources for the conduct of research that is relevant to local requirements or needs;
- 4.4 Facilitate the coordination of research in Energy, Industry and Engineering conducted by various stakeholders;
- 4.5 Promote the strengthening of capacity for conducting research in Malawi; and
- 4.6 Facilitate the translation of research findings into policy and practice.

5 METHODOLOGY

Stakeholder consultations were carried out through questionnaires and interviews in order to identify R&D priority areas in energy, industry and engineering. The identified R&D priority areas were reviewed in order to come up with research questions. Gap analysis was performed and prioritisation of R&D areas was done. The, draft Research Agenda was then developed and circulated to stakeholders for feedback and validation.

5.1 Stakeholder Consultations

Stakeholder consultations were carried out to get views on research needs and ideas from both those involved in research and those who access and use research knowledge in policy development and practice. Structured questionnaires were used to identify areas of research and development in energy, industry and engineering that are relevant for the social-economic development of the country. The questionnaires were administered to stakeholders electronically and in hard copies followed by face to face interviews wherever necessary. Stakeholders comprised research and development institutions, universities, government departments, private sector organizations and public institutions amongst others.

5.2 Review of Identified R&D Areas and Formulation of Research Questions

A task team comprising members from the National Committee on Energy, Industry and Engineering Sciences (NCEIES) was put in place to appraise responses from stakeholders consulted.

The task team accomplished the following:

- (a) Reviewed all submissions and scrutinized the list of R&D areas as identified by stakeholders for consistency and alignment to the MDGS II, the Economic Recovery Plan, the National Science and Technology Policy and the National Export Strategy;
- (b) Consolidated the R&D areas identified by stakeholders; and
- (c) Formulated research questions from the identified R&D areas.

5.3 Prioritisation of R&D Thematic Areas and Activities

Prioritisation of the R&D thematic areas as well as activities within each thematic area was done to ensure that the limited resources (personnel, finance, time, infrastructure etc) should be focused on those issues that are deemed most critical to the socio-economical development of the country and practical to address. Each of the identified research area was analysed according to a five point criteria as follows:

- (a) Appropriateness (Should the research be done?)
- (b) Relevancy (Why should the research be done?)
- (c) The chance of success (Can the research be done?)
- (d) Impact of the research outcome (What do the stakeholders benefit from the research?)
- (e) Level of innovation of the research (How innovative is the research?)

Each of the identified priority areas was scored against the above mentioned criteria on a scale of 0-3 and ranked accordingly. Any research area that scored more than 10 from a maximum score of 15 was prioritized.

5.4 Drafting of the Research Agenda

A team comprising members of the NCEIES drafted the Research Agenda and also served as an editorial team. The list of members is shown in Annex 2.

5.5 Stakeholders Consultation

The draft Research Agenda was circulated electronically to key stakeholders for their input and comments which were later incorporated into the final document.

6 PRIORITY AREAS OF RESEARCH AND DEVELOPMENT IN ENERGY, INDUSTRY AND ENGINEERING

The key R&D priorities identified in the energy, industry and engineering sectors in Malawi have been organised into 11 thematic areas which are: Construction Materials; Transport and Transport Infrastructure; Agriculture and Rural Development; Engineering Design and Development; Energy; Natural Resources Management and Environment; Climate Change;

Biotechnology; Indigenous Resources and Traditional Knowledge; Information and Communications Technology; and Nanotechnology.

6.1 Construction Materials

Good housing and other physical infrastructure contributes to economic growth and poverty reduction. It adds to the reduction of the health burden from infectious and parasitic diseases and accidents. It also provides security to both humans and assets and is a large asset base and a source of income. The building and construction sector, however, faces a number of challenges such as effects of natural disasters (earthquakes, flooding, heavy winds etc) on buildings; reliance on imported and/ or expensive building materials; use of environmentally unsustainable building materials; and high energy demands. There is also need for the provision of cost effective high quality materials for high-tech infrastructure and transport designs.

6.1.1 Priority areas of research and development

- 6..1.1 Prediction and assessment of the effects of natural disasters including earthquakes, tremors, and flooding on buildings and other physical structures including production of geo-hazard zonation maps; and development and promotion of low cost early warning systems;
- 6..1.2 Adoption, development, optimisation and promotion of construction materials and practices to minimise impacts of natural disasters (such as earthquake/ tremor, flooding etc);
- 6..1.3 Manipulation of properties of materials at the molecular or atomic level using nanotechnology in order to give rise to products:
 - with enhanced properties,
 - faster production processes,
 - lower production costs,
 - much smaller manufacturing equipment,
 - cleaner environment or new manufacturing systems.
- 6..1.4 Assessment, development and promotion of:
 - alternative construction materials (to replace cement; burnt bricks; corrugated iron; wood; etc) and practices that are sustainable and affordable without compromising on quality, durability and safety;
 - low cost multi-storey structures to maximize on the use of space without compromising on durability and safety; and
 - low cost and low energy intensity and low greenhouse gas emission processes for production of building materials and construction technologies.

6.2 Transport and Transport Infrastructure

An efficient and sustainable transportation system provides better connectivity to local, regional and international markets and promotes competitiveness of products. A reliable transportation system reduces cost of production and marketing of goods and services through, among other things, reduction in lead times. Furthermore, the provision of high quality and affordable transport improves access to social services such as education, health, markets and communication facilities. Thus investment in the transport system plays a major role in socio-economic development. Despite notable improvements made to the transport system; there are critical issues that are negatively impacting on the performance of the transport sector, which include: high construction costs; inadequate investment in construction machinery; reliance on imported and expensive vehicles and fuels; congestion of roads especially in urban areas; impact of transport emissions onto the environment; high transport costs; poor condition of most ports; poor condition of most feeder roads especially in rural areas; poor condition of railway infrastructure; ageing fleet of water vessels and a declining airline industry.

6.2.1 Priority areas of research and development

- 6.2.1.1 Assessment, development and promotion of road construction materials;
- 6.2.1.2 Improvement, optimisation and management of transport systems (rail, road, water and air) to reduce transportation costs and improve efficiency and competitiveness;
- 6.2.1.3 Assessment, adoption, development and promotion of vehicles and hybrids that use alternative fuels such as ethanol, biogas and electricity;
- 6.2.1.4 Improvement of fuel efficiency and development of alternative fuels;
- 6.2.1.5 A transportation security system applying radio frequency Identification (RFID), global positioning system (GPS), and
- 6.2.1.6 Assessment of emissions from the transport sector.

6.3 Agriculture and Rural Development

Malawi's economy is agro-based and agro-processing has potential to contribute effectively to the country's economic growth. Most of Malawi's agricultural products, however, are mainly traded as primary commodities due to poor and inadequate supportive infrastructure and low investment in agro-processing resulting in low levels of technology development. Therefore, in addition to agricultural research with special reference to bio-technology and drought management, biotic and abiotic stresses that lead to losses due to pests and diseases, research focus will be on value-addition (agro-processing).

6.3.1 Priority areas of research and development

Focusing on assessment, adoption, development, optimisation and promotion of:

- 6.3.1.1 technologies for handling, storage and preserving perishable products to prolong shelf life;
- 6.3.1.2 agro-processing equipment and other technologies to promote value addition of agriculture products aimed at (a) optimising the entire production chain from primary production systems, through postharvesting, storage and preservation, transport and marketing to value addition, both on and off farm and (b) encouraging growth of rural non-farm enterprises;
- 6.3.1.3 agro-processing technologies to improve productivity and quality in order to promote competitiveness at both local and international markets;
- 6.3.1.4 development and adaptation of technology for value addition to farm waste;

6.4 Engineering Design and Development

For the manufacturing sector, which currently contributes only about 11 per cent of the GDP to contribute more to Malawi's economic growth, and to reduce the impact imports of imported manufacturing technologies on foreign currency reserves, there is an urgent need for endogenous manufacturing engineering design and development which, in addition, will nurture and foster increased development of competitive products and systems.

6.4.1 Priority areas of research and development

Focusing on assessment, adoption, development, optimisation and promotion of:

- 6.4.1.1 metal reuse/recycle technologies from locally available materials/waste materials for import substitution, costs reduction and promotion of industrialisation;
- 6.4.1.2 plastic production/reuse technologies from locally available materials/waste materials for import substitution, reducing costs and promoting industrialisation;
- 6.4.1.3 technologies for processing of locally available materials (minerals, wood, clay, limestone, sand etc) for import substitution;
- 6.4.1.4 low cost, and low energy/energy efficient technologies;
- 6.4.1.5 alternative fuelled vehicles (battery/electric, gas, fuel cells, solar, bio-fuels) to petroleum fuelled vehicles to reduce the reliance on imported fuels; and contribute to the improvement of the environment and reduction of greenhouse gases;
- 6.4.1.6 production/manufacturing facilities; technologies; and practices for local and international accreditation to promote trade;
- 6.4.1.7 process improvement technologies and practices (labour saving technologies, maintenance programmes, use of low cost materials, waste minimisation, process control etc) to improve quality, efficiency and

- productivity; and reduce production costs hence producing goods and services that are competitive locally and internationally; and
- 6.4.1.8 development and production of machineries, equipment and tools required by industry for manufacturing.

6.5 Energy

A well-developed and efficient energy system is vital for the social-economic development of any country. Access to modern energy services contributes to high economic activity and productivity, high quality of life and encourages new investments across the country particularly in the sectors such as mining and manufacturing. The energy sector in Malawi, however, continues to face a number of challenges. The capacity to generate electricity is inadequate resulting in frequent blackouts and brownouts. In Malawi heavily the transport sector relies heavily on energy derived from imported petroleum products. The country occasionally experiences shortages of gas and liquid fuels due to a number of factors including logistical and foreign exchange problems. Furthermore, only 7 per cent of the population is connected to the national electricity grid and leaving the majority of the population that is reliant on biomass fuel for cooking, tobacco curing, lumber extraction and brick burning.

Rapid population growth, climate change and deforestation have led to diminishing biomass resources that have become difficult to source. In addition, use of traditional cooking methods lead to incomplete combustion of the fuelwood and high levels of indoor air pollution. While mineral fuels are limited, the agricultural production of biofuels is becoming increasingly viable and desirable. There is therefore urgent need for research and development focusing on energy sources for electricity generation, improved energy use efficiency and, alternative and renewable energy.

6.5.1 Priority areas of research and development

6.5.1.1 Renewable energy

- Identification of suitable crops for bio-fuel production;
- Development of engineering plants of different capacities;
- Breeding for bio-energy traits (e.g., high biomass grasses);
- Assessing environmental impact of using bio-fuel and the economics thereof;
- Developing and adapting technology for alternative energy sources like geothermal, biogas, biomass, water, waste, wind, and sun;
- Investigation of the potential of photobioreactor systems, growing algae to produce biodiesel, using CO₂ captured from power stations,
- Using plastics, biological materials and nano-particles for harnessing solar energy, and

- Adoption, development, optimisation and promotion of:
 - hybrid energy systems (water/ wind/ solar/ geothermal/ and biomass) and energy technologies to increase and improve energy generation; and
 - mini and micro hydro-power technologies for electricity generation in order to increase and improve energy generation.

6.5.1.2 Non-renewable energy

- Assessment, adoption, development, optimisation and promotion of:
 - co-combustion (coal combustion and biomass co-combustion etc) technologies for electricity generation and industrial processing;
 - coal conversion technologies for production of diesel fuel;
 - waste plastic conversion technologies for production of fuel oil;
 - coal resources and efficient combustion technologies for electricity generation, industrial processing and household use.

6.5.1.3 Energy efficiency and conservation

- Assessment of various energy generation, distribution, and utilisation systems and strategies (off grid, communal, grid, regional interconnectivity etc);
- Adoption, development, optimisation and promotion of:
 - electrical energy efficiency technologies and practices during production, transmission, distribution and utilisation at all levels (household, transport, agricultural and industrial);
 - energy efficiency technologies and practices for cooking, heating and drying (efficient cookstoves and solar energy) at all levels (household, community and industrial); and
- efficiency technologies and practices during transportation and utilisation at all household, transport, agricultural and industrial levels.

6.6 Natural Resources Management and Environment

In Malawi like in any other developing country, natural resources play a significant role in socioeconomic development. Approximately 80 per cent of the country's population depend on natural resources for their subsistence and household income. Increasing population growth coupled with high poverty levels have, however, led to an increase in exploitation of natural resources. Inadequate alternative livelihoods, unaffordable energy technologies and uncoordinated policies have exacerbated environmental degradation leading to social and economic consequences. There is, therefore, need for a programme that focuses on the development of ST&I that are useful in effectively managing natural resources and environment and mitigating against natural and man-made disasters. Malawi has abundant mineral

resources that include bauxite, heavy mineral sands, monazite, coal, uranium, precious and semi-precious stones, limestone, niobium, dimension stones and rock aggregates. These resources, however, are not fully exploited due to undeveloped mining industry.

6.6.1 Environment

6.6.1.1 Priority areas of research and development

- Quantification of the impacts of management practices on soil carbon and parameterisation of models of soil carbon dynamics for agricultural and forest systems.
- Quantification of environmental footprint of major crop and livestock production systems on the soil, water and atmospheric environment.
- Development of improved models of sequestration for dryland forest species and mixed-species re-vegetation.
- Eco-restoration- Biodegradation of toxic and waste effluents and bio restoration of habitats
- Exploitation of the biosynthetic and bio catalytic capacities of the microbial communities in waste management and pollution mitigation.
- Development of treatment strategies based on metagenomic knowledge
- Prospecting of catabolic genes from common effluent treatment plants
- Metagenomic of biofilm/community in removal of volatile organic Carbon
- Research into the role of forest products in climate change mitigation.
- The effect of landfill type, management and environment on the rate and extent of decomposition of wood and paper products.
- Sustainable waste management (waste management hierarchy: avoidance, reduction, reuse, recycling and disposal) technologies and strategies including resource recovery;
- Rehabilitation of degraded environment and prevention of environmental degradation.

6.6.2 Natural Resources Management

6.6.2.1 Priority areas of research and development

- Synoptic observations (surveying, monitoring and inventory) using remote sensing in agriculture, hydrography, geology, mineralogy, land cover, land use and environment.
- Increasing forest cover through reforestation.
- Enhancing forest value through product development (e.g., aloe, gums and resins).
- Commercial tree plantations and carbon sinks.

- Rehabilitation of soil degradation.
- Rehabilitation of ecosystem and management of wildlife.

6.6.2.2 Mineral Industry

- Building capacity and capabilities for mineral resource exploration and exploitation,
- Establishing and implementing resource based human conflict mechanisms in the mining zones,
- Determining the national mineral resource base.
- Increasing and promoting efficiency in mining and value addition in mineral processing.
- Assessment, development, optimisation and promotion of:
 - low cost technologies and practices for small-scale sustainable mining; and
 - technologies and practices for local processing/ value addition of minerals.
- Preliminary assessment and quantification of mineral resources;
- Development and promotion of sustainable exploitation of mineral resources;
- Determination of the national mineral resource base; and
- Assuring efficiency in mining and value addition in mineral processing

6.6.2.3 Water and Sanitation

- Monitoring eutrophication and salinisation of water bodies.
- Assessment, adoption, development, optimisation and promotion of:
 - water saving and water recycling technologies at household, industrial and agricultural levels;
 - rainwater harvesting technologies for household, industrial and agricultural use;
 - low cost water processing technologies for household, industrial and agricultural use;
 - low cost sustainable wastewater treatment technologies for resource recovery and costs reduction;
 - technologies and practices that can reduce vandalism of water and sanitation infrastructure;
 - low cost sustainable sanitation options, with special attention to the needs of the poor, women, children and other vulnerable/ marginalised groups; and
 - low cost water lifting technologies for household, industrial and agricultural use.

6.7 Climate Change

Malawi experiences a number of adverse climatic hazards such as prolonged dry spells, droughts, unpredictable rainfall patterns, floods and increased temperatures. Climate change effects result in loss of human and animal life; compromised water quality leading to diseases such as diarrhoea, cholera and malaria; and infrastructure loss. In addition, effects of climate change have adverse impacts on agriculture, fisheries, wildlife, gender, energy, education, health, and forestry. It is estimated that in 1992 drought reduced the country's maize production by 60 per cent of its normal year production bringing about a 10 per cent reduction in the country's GDP. Changes in climate and ecology are also known to increasingly alter directly the transmission of many infectious diseases, with vector- and water-borne diseases being likely to produce the greatest burden of disease. There is therefore an urgent need for Malawi to endogenously develop technologies and capacities able to predict, monitor and mitigate impacts of climate change on human health, agricultural and forestry sectors as well as water resources.

6.7.1 Priority areas of research and development

6.7.1.1 Health

- Application of systems-based research on environmentally induced transmission pathways of vector-borne diseases.
- An assay of mechanisms for climate change affecting pathogens and vectors
- Study of mechanisms for climate change affecting pathogens and vectors
- Develop data observatories for environment-related infectious diseases of poverty.
- Determination of interactions between climate change and health determinants.
- Develop models to assess climate change impacts on infectious disease transmission.
- Determination of environmental and climate impacts on malaria
- Monitoring of impacts of climate change on ticks and tick-borne disease
- Development of new technologies and methodologies to better manage infectious diseases of poverty.
- Improvement in methods of surveillance for climate sensitive diseases.

6.7.1.2 Agriculture and Forestry

- Breeding for increased tolerance of water stress and improved nutrient use efficiency; tolerance of high temperatures during grain fill; quicker maturity; and lack of requirement for winter chill for bud burst.
- Extending introduced species into medium-low rainfall 'dry margins' environments,

- Research into the interactive effects of increased atmospheric carbon dioxide in a water- and nutrient-limited environment on growth of major crop, pasture and forest species.
- Research into the impacts of climate change on product quality, in all agricultural and forest systems.
- Research into the impacts of climate change on pests and diseases and resulting impacts on plants and animals.
- Development of strategies for minimising water losses on-farm.
- Improved water use efficiency for irrigated agriculture.
- Development of systems to minimise heat stress in the intensive livestock industries.
- Developing perennial legumes for hot/dry conditions (where lucerne is not persistent).
- Developing perennial grasses for low rainfall areas that are especially sensitive to changes in climate, drought tolerance and climate variability.

6.7.1.3 Water Ecosystems

- Evaluation of impacts of alternative management and harvest strategies using large scale biogeochemical ecological models;
- Monitoring systems to understand impacts of climate change especially on recreationally and commercially harvested fish and invertebrates;
- Research into impact of climate change on ecological health;
- Evaluation of adaptation strategies for freshwater fisheries.

6.8 Biotechnology

Biotechnology is a set of techniques employed for the genetic modification of living organisms, used to exploit and modify living organisms so as to produce new intellectual property, tools, goods, products and services. The techniques include tissue culture and recombinant DNA techniques, bioinformatics and genomics, proteomics and structural biology. Use of biotechnology, in which plant breeders use mutagens to modify the genes in agricultural and crop plants in order to obtain desired traits, has caused green revolution to be witnessed in the agricultural industry. Use of biotechnology has led, and continues to lead, to a multiplication of biotechnology products among which are genetic modified organisms (GMO) such as transgenic crops and commercialised drugs that are used to treat diseases such as cancer, arthritis and heart disease. Vaccines and hormones, which in the past were obtained only by the process of extraction from animal tissues, are now produced in genetically modified bacterial and animal cells; for example, insulin and the Hepatitis B vaccine. Crops such as maize, rice

and soybeans are being subjected to investigations as potential bearers of edible vaccines against different infections.

Some members of the public, however, fear that the process of transferring genetic material, which entails breaking the species barrier referred to as horizontal gene transfer, may cause potentially harmful genetic changes to occur. Biotechnology therefore offers many opportunities for R&D in the benefits and potential adverse effects of GM foods on human health and environmental safety.

6.8.1 Priority Areas of Research and Development

6.8.1.1 Use of Biotechnology Products

- Interactions between a GM crop and its environment; e.g., impact of gene flow from transgenic to conventional crops.
- Evaluation of the benefits and potential risks of genetically modified agricultural products.

6.8.1.2 Food and Nutrition

- R&D in enhancement of nutritional value in transgenic products

6.8.1.3 Food fortification and biofortification of food crops

- R&D in food fortification and biofortification.
- Addressing micronutrient deficiencies with a special focus on iron deficiency anaemia.
- Development of technologies to improve nutrient bioavailability, protection of vitamins from oxidation.
- Development of micro- and macro-nutrient formulations to address incidence of moderate and severe acute malnutrition in children
- Development of protocols to understand digestibility of food protein under chronic nutrition conditions.

6.8.1.4 Functional foods for health promotion

- Development of functional foods for the prevention of diseases including diabetes, obesity, and cardiovascular disease.
- Beneficial role of probiotics and prebiotics in human health.
 - Identification of probiotics and validation of health claims such as those in the treatment of such diseases as obesity, diabetes, and inflammatory bowel disorder.

- Identification of prebiotics and development of synergistic combinations of probiotics and prebiotics.

6.9 Indigenous Resources and Traditional Knowledge

Malawi is endowed with natural resources that are exploited by traditional leaders for treatments of some ailments. There is, however, need for the evaluation and updating of the extensive indigenous resources and traditional knowledge in order for the country to exploit the full potential of science, technology and innovation through generation, protection, preservation, evaluation, adding value to the indigenous resources and traditional knowledge. This will promote and enhance utilisation of the indigenous resources and traditional knowledge for national development. The impact of this effort on the latter will be significant if efforts are made to generate and effectively manage the intellectual property.

6.9.1 Priority areas of research and development

The priority research that has been identified will, therefore, focus on:

6.9.1.1 Traditional Knowledge

- Identification and pharmacological screening of medicinal plants for the treatment of various community ailments in close collaboration with community healers;
- Smoke research for conservation, cultivation and improving chemical constituents of indigenous medicinal plants;
- Investigations of the effect of storage on the phytochemical composition and biological activities of the indigenous medicinal species.
- Study of medicinal plants traditionally used for the treatment of stomach ailments;
- The study of medicinal plants used by the Venda communities to treat venereal disease and plants used to treat diarrhoea;
- The efficacy, safety and pharmacological properties of commercial herbal mixtures which are an increasingly popular form of African traditional medicine.
- Investigations of the behaviours of living organisms as early warning systems, taboos and totemic systems as indigenous environmental protection mechanisms.

6.9.1.2 Generation and Management of Intellectual Property

- Generating genomic resources on medicinal and aromatic plants to enhance the content of
- the therapeutically important product Identifying, generating, acquiring and protecting indigenous resources and traditional knowledge.
- The generation, protection, use and management of competitive intellectual property from Malawian science, technology and innovation (ST&I).

- Commercialization of IPR locally and internationally.
- Strengthen the existing Intellectual Property Rights (IPR) regime,
- Reviewing the existing Intellectual Property Rights (IPR) regime.

6.10 Information and Communications Technology

Information and communication technology (ICT) industries are the backbone of the global digital economy. It is the ICT industries that constitute key drivers of productivity growth in a knowledge-based, or technologically driven, economy. Information and communication technologies underpin innovation and competitiveness across private and public sectors and enable scientific progress in all disciplines. Use of ICT enhances the production, transportation and provision of information to the general public for human development as well as for making informed decisions. Despite the crucial role played by ICT in national development and Malawians' aspirations to have a technologically driven economy by 2020, no strategies have been put in place to develop or adapt ICT for the attainment of the aspiration. There is an urgent need for Malawi to:

- (a) intensify training efforts to build capacity in ICT,
- (b) join other nations in developing high-tech vibrant, affordable and globally competitive ICT infrastructure and technology that will ensure efficient service delivery in all sectors of the economy including supporting the business process outsourcing,
- (c) integrate information management and communication and popularize the use of ICT,
- (d) provide a stable umbrella for public private sector growth, and
- (e) improve delivery of service through an e-government strategy.

For all this to be achieved there is need for an enabling environment for attracting public-private partnership arrangements to be created. Given in this Agenda are priority areas that aim to Developing and adapting ICT, promoting the utilisation of ICT products and improving delivery of services are the priority areas that have been identified with particular attention to rural and underserved communities.

6.10.1 Priority areas of research and development

- Software development.
- Micro- and nano-electronic technologies, photonics.
- Telemedicine, remote health monitoring, drug delivery using RFID and biosensors
- Remote surgery using haptic interfaces, virtualization, and advanced network technologies
- Bioinformatics and biomedical computing

- Mobile monitoring, detection of adverse health events through sensor-based and wearable computing
- Pollution monitoring using adaptive sensor networks
- Energy-efficient ICT for data centres and Internet infrastructures
- ICT for energy-intensive industries
- Adaptive safety systems using RFID
- Remote, sensor-based detection systems connected to geo-spatial information systems
- Mobile ad-hoc networks for immediate disaster relief.
- Assessment, adoption, development, optimisation and promotion of technologies and practices to increase and improve usage and adoption of ICT in both rural and urban areas.

6.11 Nanotechnology

One nanometre (nm) is equal to one billionth of a metre and nanotechnology is the development and use of techniques used in studying physical phenomena and developing new devices and material structures in the physical size range of 1-100 nanometres. Nanotechnology so impacts all areas of people's lives, including materials and manufacturing, electronics, new computing systems, telecommunication and information technologies, medicine and health, the environment and energy storage, chemical and biological technologies and agriculture that it is expected to be in widespread use by 2020.

6.11.1 Priority areas of research and development

- Nanoelectronics.
- Nanomaterials and manufacturing.
- Nanotechnology solutions to sustainability issues related to energy storage and conversion.
- Nanotechnology solutions to water, sanitation and waste management.
- Nanoagriculture, e.g., Nanoparticles-mediated gene or DNA transfer in plants for:
 - development of pest-resistant varieties,
 - improving the nutritional qualities of food and smart packaging system etc.
- Nanomedicine and health, e.g.,
 - Designing of new therapeutics and targeted drug delivery vehicles for cancer, arthritis, neurological and other important diseases
 - Novel formulations to enhance the efficacy of existing drugs and expand their therapeutic spectrum
 - Nano carrier systems for siRNAs therapy

- Diagnostics and imaging for early disease detection
- Design and development of smart nanomaterial for bio separation, tissue engineering and other medical applications

7 IMPLEMENTATION STRATEGIES

It is important that all stakeholders (government, R&D institutions, private sector, NGOs and all interested parties) be actively involved in order for the Research Agenda to be effectively implemented. Some of the strategies put in place for the effective implementation of the Research Agenda are:

- R&D institutions to incorporate the identified R&D priority areas of the Research Agenda in their R&D programmes;
- Funding priority be given to R&D projects in the identified R&D priority areas;
- R&D teams for specific priority areas be formulated comprising researchers from different institutions and different areas of expertise to enhance collaboration and knowledge sharing.

A detailed action plan with budget is shown in Annex 1.

8 FINANCING MECHANISM OF THE RESEARCH AGENDA

Financing of research and development in the identified priority areas is critical for the realization of the goal and objectives of this Agenda. Stakeholders are, therefore, urged to support, financially or otherwise, R&D which is geared towards addressing priorities outlined in the Agenda. The following financing mechanisms shall be pursued.

8.8 Research Grants Scheme

The NCST through the Science and Technology Fund shall commit direct resources at various levels to support the undertaking of research and development in the identified priority areas.

Researchers and all other stakeholders wanting to undertake research in the identified priority areas shall be encouraged to take advantage of existing national and international research grant schemes which are occasionally advertised. This shall be carried out through the development of R&D proposals which shall be submitted to prospective funders (government, private sector, international organisations, NGOs etc).

8.9 Public and Private Partnerships

Public and private partnerships shall be an important vehicle for nurturing resource mobilization for research in the priority areas. Promotion of partnerships between R&D institutions and private sector/ users of R&D results shall be vital to attract research funds in areas of mutual

interest. Efforts in cultivating a culture of corporate social responsibility to support the financing of R&D in the priority areas at various levels shall be promoted.

8.10 Other financing mechanisms

R&D institutions shall make deliberate efforts to:

- Allocate funding for R&D activities in the priority areas.
- Strengthen capabilities in searching, identifying and sharing of information on all potential sources of funds for research and development across the world to enhance access to and use of international research funding possibilities; and
- Engage in activities that will build capacity in proposal writing and research skills that will attract funding.

9 DISSEMINATION OF RESEARCH AND DEVELOPMENT FINDINGS

Researchers shall ensure that R&D results are communicated to a wider audience beyond the research community. Reporting of research and its results shall be the responsibility of every researcher and the research institution. The responsibility may be delegated to either the sponsor or any individual upon mutual agreement. Research and development communication shall entail expressed commitment to publish or disseminate the results within a specified period. It is incumbent upon research institutions to promote multifaceted and comprehensive research communication to achieve high quality research dissemination. Institutions conducting research shall have a responsibility of disseminating research results to ensure that the results reach end-users. The researchers have a responsibility of publishing and organizing events for dissemination of research results.

All approved research studies shall have a component on dissemination of results and shall be budgeted for. Institutions shall also be required to establish budget lines for dissemination of research results. The NCST shall establish research data banks and repositories and compile annual directories of research in order to facilitate access and availability of research data and information for use by researchers, end-users and other relevant stakeholders. The NCST shall ensure that research and development information is available for utilisation at the national level by policy makers, communities, target populations, researchers and all other relevant stakeholders. It is, therefore, the intention of the National Research Agenda to stimulate interest that will generate research evidence in the identified priority areas.

10 COMMERCIALISATION OF RESEARCH RESULTS

Commercialization will translate the research results into new product and services which can either be exported or substitute imported products and improve existing products and services thereby creating employment, improving production and productivity. As a result this will contribute to the socio-economic development of the country as the economic status of more people will improve as they get employed; foreign exchange requirements for importation of goods and services will be reduced since imported goods and services will be replaced with locally produced goods and services; and foreign exchange earnings for the country will improve as more goods and services will be exported. In addition by improving production and productivity Malawi will be able to produce goods and services which can effectively compete with those from other countries. It is therefore required to review various models on commercialisation that would be adopted; research projects to incorporate commercialisation of the research results; encourage R&D institutions to have innovation hubs and incubation centres which would take forward any research towards commercialisation; and enhancement of the relevant policies that promote commercialisation (Intellectual Property policy, Innovation Policy etc).

The NCEIES will therefore work with other committees of the Commission (such as the National Committee on Technology Transfer and Commercialization) and other relevant stakeholders to promote the commercialization of research results.

11 MONITORING AND EVALUATION OF THE IMPLEMENTATION OF THE RESEARCH AGENDA

Monitoring is a continuous assessment of project implementation in relation to agreed schedules, use of inputs, infrastructure and services provided by project beneficiaries. Evaluation is a periodic assessment of the relevance, performance efficiency and impact (both expected and unexpected) of the project in relation to stated objectives.

The tracking of the stakeholders' adherence to the Agenda shall be part and parcel of monitoring the implementation of the Agenda. The tracking will be done using tools and indicators as described below. This tracking shall benchmark the review of the Agenda.

11.8 Checklist for Submission of Project Proposals for Registration and Review

All R&D activities carried out shall be registered (both proposals and completed projects) with NCST. Checklists for submission of project proposals for registration with NCST and review by NCEIES shall contain an element of the study addressing any of the priority areas.

11.9 Monitoring and Evaluation (M&E) Reports

The NCEIES shall be supported by NCST in order to undertake inspections and M&E visits to registered R&D activities being conducted. The NCEIES shall also be required to produce M&E reports after the visits.

11.10 Progress and Final Reports

The NCEIES shall ensure that progress reports of R&D activities undertaken in the priority areas are produced. Progress and final reports shall be submitted to NCST and R&D institutions that approved the study as per stipulated guidelines and standard operating procedures. At the end of each research study, a final report shall be deposited with the R&D institutions that approved the R&D activity with two copies submitted to NCST.

11.11 Database and Directory of Research and Development Activities

Database and directories of approved/ registered research and development activities carried out in the priority areas shall be compiled using final reports of R&D activities deposited with NCST and R&D institutions.

11.12 Review of the Agenda

This Agenda has a lifespan of five years. Informed by emerging issues in engineering, energy and industry, and the above stated indicators for tracking the stakeholders' adherence to the implementation of the Agenda, there would be an evaluation after two years to coincide with the end of the MGDS II followed by a final review of the Agenda after five years.

12 LIST OF SOURCE MATERIALS

Report on Malawi's climate technology transfer and needs assessment under United Nations framework convention on climate change (UNFCCC)-expedited phase II - Environmental Affairs, Department, Ministry of Natural Resources and Environmental Affairs. Lilongwe, Malawi, March 2003

Economic Recovery Plan - Ministry of Economic Planning and Development; Malawi Government, Lilongwe, 2012

The Malawi Growth and Development Strategy II (2011-2016) - Ministry of Finance and Development Planning; Malawi Government, Lilongwe, 2011

The Science and Technology Act (2003)

Research Policy, Focus Areas, Guidelines and Regulations (Third Edition) - Directorate of Research and Postgraduate Studies, Sokoine University of Agriculture, Morogoro, Tanzania. ISBN 978 9987 640 98 0. August, 2010

National Export Strategy (2013 – 2018): Volume 1 - Ministry of Industry and Trade; Malawi Government, Lilongwe, December 2012

The National Science and Technology Policy (2002)

The National Health Research Agenda for Malawi - Ministry of Health, Lilongwe, Malawi, January, 2012

National Energy Policy - Malawi Government, Ministry of Energy and Mining, 2003, Lilongwe

ANNEX 1: Research Agenda in Engineering, Energy and Industry – Action Plan

	Strategic Action	Activities	Period	Lead Institution	Budget (US\$)	Comments
1	Publicize Research Agenda	Publish and print Research Agenda	Mar – Sept 2017	NCST	5,000.00	
		Post Research Agenda on websites of NCST and of stakeholder institutions	Mar-17	NCST	-	
		Send electronic and hard copies to R&D institutions, professional bodies, donors, private sector etc	Mar-15	NCST	357.14	
		Hold consultation meeting with various stakeholders (R&D institutions, professional bodies, donors, private sector etc) to promote the Research Agenda	Jul - Dec 2017	NCST & NCEIES	22,142.86	
		Advertise in major newspapers and various fora	July – Sept 2017	NCST	3,571.43	
		R&D institutions encouraged to incorporate the Research Priorities Areas into their R&D programmes	July – Sept 2015	NCST, NCEIES & R&D Institutions	-	
2	Lobby Government for funding of research	Operationalise the S&T fund	Jul – Dec 2017	NCST	-	
		Organize meeting with parliamentally committee on S&T to sell the Research Agenda	Jan – Jun 2018	NCST & NCEIES	15,000.00	
3	NCST through the Science and Technology Fund to commit direct resources at various levels to	Call for R&D proposals in the priority areas	Jul 2018 – Dec 2022	NCST	-	This is dependent on the operationalising of the S&T fund
		Review of proposals	Jul 2018 – Dec 2022	NCST & NCEIES	25,000.00	

	Strategic Action	Activities	Period	Lead Institution	Budget (US\$)	Comments
	support the undertaking of research and development in the identified priority areas	Provide grants for R&D projects	Jul 2018 – Dec 2022	NCST	-	
		Implement projects in priority areas	Jul 2018 – Dec 2022	Research Teams	-	
4	Develop research proposals for submission to prospective funding agencies (Government, donors, NGOs, international organisations, public sector, etc)	Formulate multidisciplinary and multi-institutional research teams	Jul – Sept 2017	NCST & NCEIES	7,857.14	
		Capacity building in R&D proposal development and project implementation	Oct – Dec 2017	NCST	14,285.71	
		Provide support and organize workshop on proposal development	Jan – Mar 2018	NCST	10,714.29	
		Formulate and write collaborative research proposals for specific priority areas. Proposals should include at least one flagship project for each of the priority areas. The flagship projects are to integrate the knowledge side (research, adaptation, etc), and the business side (business plans, models etc) with particular focus on creating a competitive advantage for Malawi over other countries	Apr 2017 - Oct 2018	NCST, NCSIE & R&D Teams	22,142.86	
		Solicit funding for flagship project from prospective funding agencies	Jul 2017 – Dec 2019	NCST & NCEIES	10,714.29	
		Implement R&D projects in each of the priority areas	Oct 2017 – Dec 2022	NCST, NCEIES & R&D Teams	10,714,285.71	
6	Strengthen capabilities in	Identify/ nominate Lead Researchers in each of the R&D priority areas for each of the R&D institutions	July – Sept 2017	NCST & R&D institutions	-	

	Strategic Action	Activities	Period	Lead Institution	Budget (US\$)	Comments
	searching , identifyin g and sharing of informati on on all potential sources of funds for research and developm ent across the world to enhance access to and use of research funding possibiliti es locally and internatio nally	Develop database of the Lead Researchers	Oct – Dec 2017	NCST	-	
		Share database with all the R&D institutions	Dec-17	NCST	-	
		Share information on local and international funding possibilities/ call for proposals	Oct 2017 – Dec 2022	NCST & Lead Researcher s	-	
		Develop collaborative R&D proposals for funding consideration (with emphasis on proposals addressing the priority areas)	Oct 2017 – Dec 2022	Research Teams & NCST	10,714.29	
		Implement collaborative R&D projects	Oct 2017 – Dec 2022	Research Teams	-	
7	Promote partnersh ips between R&D institution s and private	Consult private sector to identify areas of collaborative research to meet their industrial needs	Jul 2017 – Dec 2017	NCST & Lead Researcher s	10,714.29	
		Develop collaborative R&D proposals	July 2017 – Dec 2022	Research Teams & Private Sector	10,714.29	

	Strategic Action	Activities	Period	Lead Institution	Budget (US\$)	Comments
	sector/ users of R&D results to attract research funds in areas of mutual interest	Implement collaborative R&D projects	July 2017 – Dec 2022	Research Teams	3,285,714. 29	For co-funding of projects
Total					14,168,928 .57	

Note: Critical to the successful implementation of the Research Agenda is the availability of financial resources

ANNEX 2: List of Member Organisations for the National Committee on Energy, Industrial and Engineering Sciences (NCEIES)

- i. University of Malawi (The Polytechnic)
- ii. Malawi Industrial Research and Technology Development Centre
- iii. Mzuzu University
- iv. Malawi Institution of Engineers
- v. Malawi Energy Regulatory Authority
- vi. Malawi Confederation of Chambers of Commerce and Industry
- vii. National Construction Industry Council
- viii. Ministry of Energy
- ix. Ministry of Transport and Public Infrastructure
- x. Technical, Entrepreneurial and Vocational Education and Training Authority
- xi. Ministry of Agriculture, Irrigation and Water Development
- xii. Malawi Bureau of Standards
- xiii. Lilongwe University of Agriculture and Natural Resources
- xiv. Department of Agriculture Research Services (Chitedze Research Station)
- xv. Department of Science and Technology
- xvi. University of Malawi (Chancellor College)

Annex 3: List of Members of the Drafting Committee

- i. Dr Moses Chinyama (Chairman)
- ii. Mr. Welton Saiwa (Vice Chairman)
- iii. Mr. John Taulo
- iv. Mr. Emmanuel Mjimapemba
- v. Dr. Hendrex Kazembe-Phiri
- vi. Mr. Arthur Wengawenga
- vii. Mr. Stephen Chalimba
- viii. Mr. Macpherson G. Matewere
- ix. Mr. Ebony Msikawanthu
- x. Mr. Kondwani Thapasila Gondwe
- xi. Mr. Joseph Kalowekamo
- xii. Mr. Emmanuel Mkomwa
- xiii. Mr. Rex Kanjedza
- xiv. Dr. Patsani Kumambala
- xv. Mr. Albright Mchemba
- xvi. Mr. Victor Luwambala
- xvii. Mr. Rodgers Banda
- xviii. Mr. Caspah Kamunda
- xix. Dr. Christopher Guta
- xx. Mr. Chimwemwe Mtegha
- xxi. Mr. Fredrick Wazingwa Munthali