Theme 3. Energy, Engineering, and Information Technologies

Globally, humanity faces profound challenges in meeting increasing energy demands in the face of climate change and the skyrocketing oil prices. Ethiopia is no exception. In particular, lack of alternative energy has led to deforestation, land degradation, desertification, and food insecurity in the country. Apart from energy needs, the need for modern and cost-effective construction has also become vital. Information is also imperative as a source of wealth and development in the modern knowledge and information society in the country. Therefore, high investment in energy, engineering, and information technology is vital for economic development of Ethiopia.

Despite the existence of high untapped potential of green energy, Ethiopia faces unprecedented energy shortages parallel with its huge development endeavours. Similarly, the country has seen huge increases in construction activities that require proper planning, designing, implementing, monitoring, and evaluation. However, the country's construction industry is characterized by delays in meeting project durations, increase in total cost of the projects, resulting in bankruptcy of companies, descent in construction quality, serious question on public safety, and overall project failures.

On top of the above problems, agriculture in Ethiopia is predominantly carried out using traditional and ancient technologies. Therefore, it should be supported with mechanization and other improved technologies that can be afforded by smallholder farmers. The technologies include those that ease work burdens and increase efficiencies of agricultural operations. Improved tools, implements, equipment, and powered machinery are essential for enhancing agricultural productively, marketing, and post-harvest management.

Sub-theme 3.1. Information Technology and Computing

Rationale

Information is an imperative and abstract material that is considered as a source of wealth and development in the modern society. Creating knowledge and information using information technological findings and statistical and computational studies will empower decision makers to make up-to-date solutions and improve the day to day life of the society at large.

The community could benefit from both action and scientific research conducted within the sub-theme. In addition, research findings would benefit the infant hardware and software industries of Ethiopia by competing and cooperating with companies, institutions, and agencies worldwide.

Aim

The aim of this sub-theme is to analyse, design and/or develop ICT solutions and conduct computational and statistical analyses to solve problems of the community.

Description

This sub-theme focuses on three areas, computer and information technology development and advancement, statistical modelling, and scientific computing. This sub-theme focuses on providing computational, statistical, and technological outcomes to the community. It also involves need and impact assessment of computational and information technological outputs.

Potential Collaborators

National and overseas universities, Ministry of Science and Technology, ICT industries, Non-governmental organisations, international agencies, funding institutions, the community, policy makers, and other stakeholders.

Expected Output

- Software solutions, packages, network designs, improved algorithms and intelligent systems

- Identified and addressed knowledge gaps in the area of computers and information technology and systems

- Promoted ICT roles in interdisciplinary perspectives

- New and enhanced/localized software development methodologies

- Statistical models for various socio-economic features of the community

- Developed computer models and simulated environments

Research Areas

3.1.1. Formulating, developing, and enhancing information technologies

The research area focuses on new and localized software and hardware technologies that can bolster the development endeavours in the country and pave the way towards new theories and applications. It also focuses on formulating, developing and enhancing information technologies that can solve various problems. It includes research on cloud computing, mobile ad-hoc networks, intelligent system, and artificial intelligence.

3.1.2. Development and application of statistical methods

Research in this area focuses on development and applications of statistical methods, which are useful in monitoring various conditions as well as assisting the development of optimum policies.

3.1.3. Developing mathematical and computational theories

This research area deals with formulating mathematical theories and equations that need semi-high performance computing facilities. It encompasses modelling, simulation, image

processing, optimization, data mining, classification, etc. Modelling in particular is focussed on models that are used to support the implementation of executable versions on computers while the execution of a model over time is understood as a simulation. In the process, tailor-made algorithms based on needs or identified problems will be developed.

Beneficiary

Industries, public institutions, scientific community, policy makers, and the wider community

Sub-theme 3.2. Advanced Material Research and Development

Rationale

Advanced material research aims at producing novel materials at macro-micro- and nano scales that have a spectrum of applications in many areas of applied sciences and engineering. Nanoscale science, engineering, and technology, which are widely and collectively termed as 'nanotechnology', is an emerging multidisciplinary field that can have enormous potential on impacting the society. Research in this sub-theme will lead to significant advances in a variety of applications including medicine, material science, agriculture and food, computing and electronics, industrial manufacturing, environmental remediation, energy production, and military applications, among others.

Aim

The aim of this sub-theme is to synthesize/fabricate and develop novel materials in macro/micro/nanoscale that have applications in areas such as energy and environment, agriculture and food, health and medicine, engineering, electronics and IT.

Description

This sub-theme focuses on the synthesis, fabrication, and device development of novel materials such as polymers, composites, hybrids, semiconductors, ion exchangers, sorbents, coordination/organometallic compounds that have unique optical, magnetic, electrical,

structural, mechanical, thermal, and other important functional properties. The functional properties are meant for development and production of solar cells, photo catalytic degradation of organic and inorganic pollutants, separation science and technology (sorption, exchange), sensor, and various other applications.

Potential Collaborators

Domestic and overseas universities, Ministry of Science and Technology, Environmental Protection Agency, Ethiopian Standards and Quality Authority, etc.

Expected Output

- Advanced materials and nanotechnologies for greener and better energy alternatives, better health and environment, and improved agricultural productivity and food packaging and delivery system.

- Better understanding and broadening of knowledge on nano-sciences and nanotechnologies

- Strengthening postgraduate education and research capacity on nano-sciences and nanotechnologies.

Research Areas

3.2.1. Fabrication/development and applications of nanomaterials and nano device

This research area focuses on nanoscale materials, which are promising candidates for improvements in alternative energy. The research area also deals with nano science technology for cleaning air, water, and soil through photo catalysis, sorption, ion exchange, nano filtration and others, nano systems for drug delivery systems, nano particulate antimicrobial coatings involving silver nanoparticles for wound care, nano emulsion, nanomaterials in food packaging and agrochemicals to deliver pesticides/herbicides. It also involves enhanced use of nanotechnology in glass, concrete, and steel technologies, in coatings such as paints to give

the coating self-healing capabilities and corrosion protection under insulation, and nanomaterials in optoelectronic, computing, and semi-conductor devices.

3.2.2. Fabrication/development of bulk materials

Research in advanced materials development is also involved in the synthesis/fabrication of novel bulk/macroscopic materials such as coordination compounds, ceramic materials, organometallics, semiconductors, alloys, composites, exchangers, hybrid materials and others with tremendous applications that add convenience to our lives. These include antimicrobial/dyeing application, materials for separation/sensing technology, electronic materials (laptop computers, digital cell phones etc.), catalytic materials, materials for energy/gas storage, and others.

3.2.3. Monitoring and control of hazardous nanomaterials

This research area focuses on validation of new advanced materials and nanotechnologies; assessment of the effects of advanced materials and nanotechnologies on human, animal and environmental health; standardisation of the products of advanced materials and nanotechnologies; control side effects of advanced materials and nanotechnologies; assess the impact of advanced materials and nanotechnologies on livelihoods; formulate policy guidelines for the production and utilisation of advanced materials and nanotechnologies.

Beneficiary

Scientific community, industries, agriculture, farmers, businesses, community at large

Sub-theme 3.3. Energy Resources Development and Utilisation

Rationale

Globally, humanity faces profound challenges in meeting the increasing energy demands in the face of climate change and the skyrocketing oil prices. In particular, lack of alternative energy sources has led to deforestation, land degradation, food insecurity, and desertification

in Ethiopia. The development and application of small-scale technologies for energy conversion and efficiency is an essential component amongst the collection of strategies for confronting these challenges. Technological progress in this field is swift with new development promising leaps in cost reduction, efficiency, and flexibility of applications. However, regardless of technical efficiency, new technologies will only make a difference as long as they are successfully integrated into people's living environments.

Ethiopia, in this regard, is bestowed with huge potential of energy sources which must be harnessed and developed. Being one of the countries that developed a policy of zero carbon emission economy by the year 2025, the nation needs to invest in research and development that guarantees a green economy. Besides, the government is striving to realise rural electrification and has also designated an ambitious plan to be the powerhouse of Africa.

The challenge in the future will be the issue of balancing energy production and supply with the ever increasing demands. We also need to deal with energy accessibility to the rural community living in a sparse environmental setting vis-à-vis exporting power to neighbouring nations with the aim of generating foreign currency.

The solution will, therefore, be research and development that may reduce the cost of energy development i.e., its production, transmission, and storage efficiency. Research will be focused on a number of areas critical to the future of energy in Ethiopia. Focus will be particularly given to policy collaborations on energy that address energy security issues, specially focusing on millions of rural Ethiopians who lack access to clean energy and are unable to climb the energy ladder. In this endeavour, a multitude of complex issues in a cross-disciplinary approach spanning science, technology, social science, and policy interventions will be researched.

Aim

The aim of this sub-theme is to provide accurate and quantitative information on energy feasibility, potential, efficiency, and synthesis of various energy sources, and characterisation and design of cost-effective photovoltaic cells that are scalable for commercial purposes.

Description

The sub-theme focuses on research to deliver a robust estimate of the temporal and spatial distribution of unutilised potential of renewable energy sources and investigates the impact of energy exploration on the environment. It investigates the physics of photovoltaic cell focusing on efficiency and low cost method of scalability. At lower levels, it also aims at investigating and developing wind turbines that could be used at household levels. The sub-theme further explores the possibility of designing energy-efficient inexpensive stoves with locally available raw materials.

Potential Collaborators

International and national institutes, organisations, universities/colleges working on energy and power

Expected Output

- Generated quantitative data on the potential of renewable energy sources in sparsely populated areas

- Generated information on efficiency and performances of wind farms, solar, geothermal, and hydropower in the country

- Designed and developed wind turbines for use at household level; and

- Synthesised, characterised and developed photovoltaic cell and modules.

Research Areas

3.3.1. Wind energy

This research area focuses on potential, feasibility, and efficiency of wind farms and developing wind turbines.

3.3.2. Solar energy

This research area focuses on accelerating the development and implementation of cost-effective solar-based technologies. The research and development activities in this area will target the development of solar photovoltaic-based devices and developing electrical energy storage in battery systems. It also focuses on photovoltaic cells synthesis, characterisation, development and construction of photovoltaic modules.

3.3.3. Hydropower energy

Hydropower research includes mechanical, civil, and electrical engineering focusing on turbine and generator development, transformer and power electronics, fluid dynamics, construction as well as environmental and economic aspects. The research area focuses on analysis of the environmental implications of hydropower schemes bringing environmental and sustainable engineering into a range of disciplinary inputs.

3.3.4. Geothermal energy

This research area focuses on innovative tools and techniques for resource exploration and development; improved investigative methods and models for more sophisticated and detailed reservoir management; advanced techniques for remote sensing and detecting potential geothermal resources; improved techniques and materials for well construction and restoration; and technologies and techniques to improve energy extraction at existing production areas.

3.3.5. Fossil fuel energy

The research focuses on research related to the exploration, feasibility study, extraction and technological innovations for improved fossil fuel development and utilisation. It also addresses problems related with research in technological innovations for fossil fuel systems, with the primary emphasis on carbon dioxide emission mitigation, and control of fine particle and other pollutant emissions.

3.3.6. Bio-energy

This research area aimed at developing bio-energy from different plant-based and other biological resources, its adaptation, and implementation.

3.3.7. Nuclear energy

This research area focuses on research related to harnessing nuclear energy as an alternative source of power. It also deals with research on the enhancement of knowledge, human power and technical capacity development for nuclear sciences. The research area also includes topics related to the application of nuclear-based technologies in health and medicine, research laboratories, etc.

Beneficiary

Scientific communities, industries, policy makers, and the wider community

Sub-theme 3.4. Postharvest Technology, Processing, and Food Analysis

Rationale

Estimates of postharvest losses reach 30% or more of food harvests. Poor postharvest practices, in turn, can affect incomes, food quality, and the long-term abilities of families and communities to escape from poverty. There is a need for the development of new technologies and practices that tackle sites of loss and contamination throughout the postharvest value chain, and identification of avenues for spreading the best existing technologies and practices. A core component is connecting farmers to appropriate markets so that sustainable intensification and reductions in crop losses can yield real returns.

Food analysis involves the development, application and study of analytical procedures for characterising properties of foods and their constituents. The analytical procedures are used to provide information about a wide variety of different characteristics of foods, including composition, structure, physicochemical properties, and sensory attributes.

Supplying adequate quantities of grains and other food items to the ever increasing world population is a challenge to humankind. Hunger and malnutrition still exist in many countries in spite of adequate food production. This is a result of uneven distribution, post-harvest losses, and deterioration of available food resources. For cereals, the overall postharvest losses are usually estimated at 5–20% whereas for fruits and vegetables, they vary from 20% to 50%. If the losses can be minimized, more food may become available to humankind.

Therefore, postharvest crop and animal product losses are an important aspect of food production, processing, distribution and marketing. Losses caused by poor post-harvest management of agricultural produces reduce yield, quality, and cause malnutrition and hunger. These problems can be tackled though developing appropriate post-harvest technologies. In eastern Ethiopia in particular farmers stores grains in pits, predisposing the produce to serious post-harvest losses with contamination with myco-toxins. This results in huge yield and quality losses as well as health hazards to humans and animals.

Aims

This sub-theme aims at analysing the process of food production from plant and animal products; developing and improving postharvest technologies for plant and animal products, and designing, developing and evaluating new food products and improving the existing traditional food product storage and processing techniques.

Description

This sub-theme focuses on development of food quality standards; improvement of quality of fresh produce, grains and animal products; development of new food products from indigenous and traditional food resources; improvement of storage and processing methods of traditional and indigenous foods and drinks; improvement of traditional processing equipment (technologies); and solving problems of nutrient deficiencies. Exploration of non-conventional food resources for the potential to develop into acceptable processed food products is also a focus of this sub-theme. The sub-theme also deals with postharvest

management, product development, and storage and processing technologies of industrially and economically important crops.

Potential Collaborators

Universities conducting research in agriculture and food related activities, federal and regional agricultural research institutes, food processing industries and NGOs involved in development programmes focusing on food related issues are potential organisations for possible cooperative research work.

Expected Output

- Improved and efficient processing methods and techniques

- Quality, safe, nutritious and healthy food products

- Demand driven product development from existing traditional foods and drinks as well as newly developed/formulated foods and food ingredients

- Minimized postharvest losses for contribution in fostering food security

- Improved traditional post-harvest technologies

- Characterized and authenticated non-conventional food products for improvement of food security

- Modelled food process technologies and controls for end users

- Efficiently utilized food wastes and by-products for energy supply and environmentally friendly applications.

Research Areas

3.4.1. Postharvest technology, processing, and food analysis for plant/crop products

The main focus of this research area will be developing and improving technologies to minimize postharvest losses of fruits and vegetables. In addition, it addresses issues on food analysis, value addition and product development as well as storage, processing, and

preservation of fruits, vegetables, tubers and root crops. The research area also addresses issues related with agro-industry.

The research area also include storage and processing technologies of raw grain crops into value added foods, grain quality characterisations, raw material and product utilisation and packaging technologies to address challenges faced by food processing industries. Moreover, this research area focuses on studies including processing of functional foods to deliver nutritious and healthy food stuff.

3.4.2. Postharvest technology, processing, and food analysis for animal products

The main focuses of this research area are analysis, processing, and developing technologies for animal products including traditional and modern meat/dairy and meat/dairy/skin and hides based food products and processing and preservation practices; honey handling, processing, quality evaluation and characterisation; fish handling, processing, quality evaluation and characterisation; starter culture developments and improvements for dairy fermented foods and beverages; animal foods based processing of functional foods; and the safety and quality of animal products evaluation and analysis.

Beneficiary

Scientific community, farmers, industries, policy makers, and the wider community

Sub-theme 3.5. Civil Infrastructure, Manufacturing, and Industrial Technology

Rationale

The construction industry is one of the major sectors which involve huge capital and human resources. Design and construction play a vital role in the national economy including the development of residential housing, office, commercial and retail buildings, industrial plants, roads, dams, irrigation schemes and the replacement, maintenance and restoration of the nation's infrastructure and other public facilities. In countries like Ethiopia, about 60% of the

annual capital budget is allocated to construction. Improved designs and construction of these facilities determines the development success of the nation.

However, the country's construction industry is characterized by delays in meeting project deadlines, increased total costs of projects, resulting in bankruptcy of companies, descent in construction quality, serious question on public safety, and overall project failures. Detail research on the design of civil infrastructure, efficient use of construction materials, improved construction methods and state of the art construction management alternatives will help to reduce the major problems associated with the Ethiopian construction industry. Noises, pollution and social problems still belie the priority accorded to sustainable development in Ethiopian urbanisation policy and strategy.

Ethiopia currently has a low level of urbanisation, with approximately 16% of its population living in urban areas. The rate of urbanisation is currently between 5-6% per year. This means doubling of the urban population every 12 years, a situation that could result in the urban population increasing from its current level of 11-12 million to over 40 million over the next 25 years.

Consumption of resources like water and energy in construction is high, while investment in research and development is much lower than in other sectors. New technologies and approaches must be developed through research endeavours to help the construction industry to adopt concepts of sustainability.

In addition to infrastructural developments, the role of designing, manufactuting and industrial technology in the overall economic development of a country is enormous. At present, the manufacturing and industrial sectors face major scientific and technological problems.

Systems of agricultural production, which are primitive, have not kept pace with the population growth. The farming methods are poorly developed; breaking the ground is done with wooden ploughs, and planting is still mostly done by broadcasting. Cultivation and harvesting are done using old and poor farm tools. Threshing is done by pounding with sticks

or by hooves of animals; winnowing makes use of wind and human labour. Tools, implements, equipment and powered machinery, are essential and major inputs in agriculture.

Aim

The aims of this sub-theme is to analyse the current practice of designing and constructing of civil works and improving the design codes and standards in order to provide a cost effective and environmentally friendly structure as well as to examine and identify best practices to measure and monitor socially sustainable urban regeneration and provision of vital services.

Description

The focus areas of the research will be construction and urban infrastructure which incorporate civil structures design and construction, geotechnical investigations, water supply and hydraulic structures, development and efficient and effective utilisation of construction materials, construction technologies and management, highway and transportation engineering, maintenance of civil structures, renovation and preservation of historical buildings and monuments, integrated urban planning and design, land use and waste management in urban areas, assessment and monitoring of civil infrastructures, and related issues.

One of the focus areas of the sub-theme is urban development and the construction industry which incorporate urban planning and design, civil infrastructure monitoring, assessment, and maintenance systems, geotechnical investigations, development and efficient and effective utilisation of construction materials, construction management and technology, planning, and economics, and policy of transportation engineering and related issues.

The other focus area of the theme is design, manufacturing and industrial technology which includes automotive innovation, advanced materials, energy and power, design and development, thermal and systems engineering, designing and manufacturing, industrial automation and control system, quality control (an engineering approach), and motor vehicle engineering.

The focus area shall also include farm power, agricultural machinery engineering and mechanisation which will deal with possible areas of research like characterisation of soils of eastern Ethiopia in terms of their physical and mechanical properties, design, construction, performance evaluation and introduction of improved tillage, planting, harvesting, and processing machinery, investigation into physical and mechanical properties of plant and animal products, studies on potential, prospect and limitation of draft animal, human being, wind, solar and bio-energies and optimum utilisation of the same.

Potential Collaborators

Ministry of Construction and Urban Development, Ministry of Transport, and Federal and Regional Road Authorities, Ministry of Agriculture, Ministry of Science and Technology, Ministry of Industry, Investment Bureaus at Federal and Regional levels, Ethiopian Academy of Science, private sector, non-governmental organisations, and international research institutes, domestic and overseas universities, infrastructure agencies, and private contractors and consulting firms

Expected Output

- Proper designs and construction of civil works aligned with optimal use of locally available materials

- Improved technology and management of construction projects

- Proper and efficient procurement, contract administration and management of construction projects

- Integrated, cost effective, convenient, and environmentally friendly urban planning

- Improve urban infrastructure planning approaches for new cities and towns.

Research Areas

3.5.1. Urbanisation, Urban development, and construction industry

This research area addresses major problems related to urban development and construction industry such as urban planning and design, civil infrastructure monitoring, assessment, and maintenance systems, geotechnical investigations, construction materials, construction management and technology, and planning, economics, and transportation engineering.

3.5.2. Designing, manufacturing, and industrial technology

This research area addresses major problems related to designing, manufacturing, and industrial technology such as automotive research and innovation, quality and productivity improvement, industrial control, processing machines and bulk material handling, and transport technologies.

3.5.3. Farm power, agricultural machinery engineering and mechanization

This research area addresses major problems related to farm power, agricultural machinery engineering and mechanisation such as characterisation of soils, design, construction, and evaluation machinery and implements, introduction of improved tillage, planting, harvesting, and processing machinery, investigation into physical and mechanical properties of plant and animal products, draught animals, development of harness.

Beneficiary

Agriculture, manufacturing industries, food processing industries, policy makers, and the wider public