Mapping University Curriculum with Energy Planning

Final Report

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Addis Ababa, Ethiopia

Published on November 2024

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Abbreviations

AAU	Addis Ababa University
AAiT	Addis Ababa Institute of Technology
ASTU	Adama Science and Technology University
Danida	Danish International Development Agency (Ministry of Foreign Affairs of Denmark)
DEEP	Enhanced Denmark Ethiopia Energy Partnership
DEA	Danish Energy Agency
DFC	Danish Fellowship Centre
DKK	Danish Kroner
EEP	Ethiopian Electric Power
EEU	Ethiopian Electric Utility
EIH	Ethiopian Investment Holdings
EiT-M	Ethiopian Institute of Technology-Mekelle, Mekelle University
IPP	Independent Power Producer
LAMC	Liability Asset Management Corporation
MoF	Ministry of Finance
MoM	Ministry of Mines
MoPD	Ministry of Planning and Development
MoWE	Ministry of Water and Energy
MoSHE	Ministry of Science and Higher Education
MoTRI	Ministry of Trade and Regional Integration
MoU	Memorandum of Understanding
PEA	Petroleum and Energy Authority
PEHA	Public Enterprise Holding and Administration
PG	Postgraduate
PPP	Public Private Partnership
RDE	Royal Danish Embassy in Addis Ababa
SDG	Sustainable Development Goal
SOE	State Owned Enterprise
STEM	Science, Technology, Engineering, and Mathematics
ToR	Term of Reference
TSO	Transmission System Operator
UG	Undergraduate

1. Executive summary

This report is a study on “Mapping University Curriculums with Energy Planning” under the Enhanced Denmark Ethiopia Energy Partnership (DEEP) programme which is being executed by the Royal Danish Embassy in Addis Ababa in partnership with the Ministry of Water and Energy of Ethiopia, Ethiopian Electric Power and Ethiopian Electric utility.

One component of DEEP is the engagement of Ethiopian and Danish universities to further enhance the transfer of knowledge between the national institutions. Specifically, three Ethiopian universities (i.e. Addis Ababa Institute of Technology - AAiT, Adama Science and Technology University – ASTU, and Ethiopian Institute of Technology – Mekelle – EiT-M) are planned to be engaged with universities from Denmark that leads to a “twinning project” which involves a possible exchange of students and staff, strengthening energy related curricula, content development and preparation of active learning materials for new courses in the field of energy planning and modelling, transmission and distribution system, wind energy development, and cross-border electricity trade.

Thus, the core objective of this mapping exercise is to produce a detailed overview regarding energy planning including the existing curriculums, taught courses, collaborations with other organisations, research capabilities and capacity gaps within the three universities.

Based on the investigation of the curriculums, it is found that EiT-M runs more energy programs than AAiT and ASTU. In terms of human capacity, EiT-M also has a greater number of academic staff who have specialized in the field of energy. With regard to research capability, this study has shown that AAiT and EiT-M have established several collaborations worldwide and they have been engaged in many research projects. The investigation also revealed that energy as a full-fledged program is not given at BSc level in any of the three universities despite having the Electrical Power Engineering program. Instead, selected energy courses are included in the undergraduate program mainly during specialization (3rd, 4th and 5th-year) in Electrical Power Engineering. However, standalone energy education is given at MSc and PhD levels in all the three universities.

This study found that the supply of highly skilled workers in Ethiopia’s energy sector is limited. Thus, special training is necessary for personnel at every level in the industry to keep abreast with rapidly advancing state-of-the-art in the energy/power industry. Unless and otherwise the utilities have a pool of committed and competent professionals equipped with appropriate technical skills to steer the sector, the country’s energy sector will remain noncompetitive and inefficient that hinders innovative advancements across sectors of the economy and reduces Ethiopia’s competitiveness in the global market.

Based on the findings of the study, various interventions and mitigation strategies are suggested such as: 1) government intervention – allocating adequate funding for renewable energy research, 2) resource sharing – among universities & industry, 3) collaboration with foreign universities and partners, 4) establish industry tailored programs, and 5) Introducing open-source energy modelling tools in the academia & industry.

1. The assignment

1.1. Background

Over the past 15 years, Ethiopia's economy has been among the fastest growing in the world, at an average of 9.5% per year, and it still has the fastest growing economy in the region, with 7.2% growth in FY2022/23. Ethiopia's long-term vision for prosperity is based on the Plan for accelerated and sustained development to end poverty, and the vision is supported by national five yearly growth and transformation plans latest 2020-2025. With about 126.5 million people (2023), Ethiopia is the second most populous nation in Africa after Nigeria and has the largest population of youth. However, it is also one of the poorest, with a per capita gross national income of $960[1]; by all measures Ethiopia is in need to expand the productive sector as a means not only to provide opportunities to sustain life in the growing urban areas but also to address the need for decent jobs for the youth.

During the period 2005-06 – 2009/10 the need for electricity grew around 25% followed by a 12% increase in demand during the following decade [*Ethiopia Energy Outlook Report, 2022*]. It is well documented that undersupply of access to electrical power is a key barrier for economic growth, and the Government of Ethiopia (GoE) regards accelerated power supply as a national priority.

With Ethiopia's present activities and planned ambition to expand its power sector, system complexity and advancement in technology; the demand for future experts is expected to be high. In this regard, universities have a crucial role of producing graduates who are equipped with the necessary skills and knowledge capable and confident to address the needs of the electric power sector in the country. However, the Ethiopian universities are not in a position to face this challenge alone. Limited knowledge within the area of energy planning and modelling, weak university-industry linkage, lack of appropriate research, education and facilities in the area are identified as major limiting factors. In light of this, collaboration with local affiliated institutions (MoWE, EEP, EEU) and foreign universities is essential.

The Enhanced Denmark Ethiopia Energy Partnership (DEEP) programme is a Government-to-Government Cooperation that aims to provide technical assistance from Danish governmental institutions (Danish Energy Agency (DEA) and Danish Transmission Operator (TSO)-Energinet) to the Ministry of Water and Energy of Ethiopia (MoWE), Ethiopian Electric Power (EEP), and Ethiopian Electric Utility (EEU). The engagement with the Danish Energy Agency has a university component that aims at engaging Ethiopian and Danish universities to further enhance the transfer of knowledge between the national institutions. Specifically, this component of the programme is initially planned to engage three Ethiopian universities and three to four universities from Denmark to facilitate 'twinning' of universities and explore the possibility of assisting Ethiopian universities in developing their curriculums within the field of energy planning and modelling, transmission and distribution system, wind energy development and cross-border electricity trade. Aiming to secure the future experts and create a sustainable change, the Danish universities are expected to

[1] www.worldbank.org Ethiopia

assist in building the capacity of these universities to develop and deliver the relevant courses and thereby produce the human capital needed to meet the demand of the energy sector in Ethiopia.

1.2. Objective and scope (of the assignment)

In light of the above background, the Royal Danish Embassy in Addis Ababa expressed its interest to engage an expert in a mapping exercise to gather information regarding the capacity of the three Ethiopian universities (Addis Ababa University - Addis Ababa Institute of Technology (AAiT), Adama Science and Technology University (ASTU) and Mekelle University – Ethiopian Institute of Technology – Mekelle (EiT-M)). This information will be the starting point from which to develop curriculums and courses relevant in the energy sector and it will serve as the basis for initiating a twinning project, which involves exchange of students and inviting guest lecturers between Danish and Ethiopian universities.

The core objective of the mapping exercise is to produce an overview regarding the courses, research activities (projects and publications) and researchers within the three universities. The focus is on energy planning and modelling, transmission and distribution system, wind energy development and cross-border electricity trade. The analysis will then be used as an input for the curriculum development and twinning exercise with the Danish universities.

The above objectives of this assignment are envisaged to be achieved through the activities but not limited to the following:

- Document the curriculums that are in place in the three universities and do an inventory of existing education programs that is relevant for the energy sector, the human capital, existing collaboration with other organisations, future plans and the capacity gaps.
- List the different energy courses that are being taught in the three universities.
- Understand the extent to which existing themes match the requirements of energy development in Ethiopia, focusing particularly on the relevance of energy planning and modelling, transmission and distribution system, wind energy development and cross-border electricity trade.

1.3. The Theory of change

The ToR of this assignment[2] and the DEEP programme document[3] added with the consultant's input include a Theory of Change, which serves to describe the logical coherence of activities leading to outputs, outcomes and impacts, that ultimately lead to achievement of overall objectives. The sequence of logic is based on the provision of input – an engagement with the DEA, now well established within EEP, that has a university component under the DEEP programme.

Building on the findings of this mapping study, the project component will strengthen the current energy curricula at each partner universities. Content development for new

[2] Appendix 2 – Terms of Reference, Mapping university curriculums with energy planning.
[3] Enhanced Danish-Ethiopian Energy Partnership (DEEP), 2023-2028, Programme Document, February 2023.

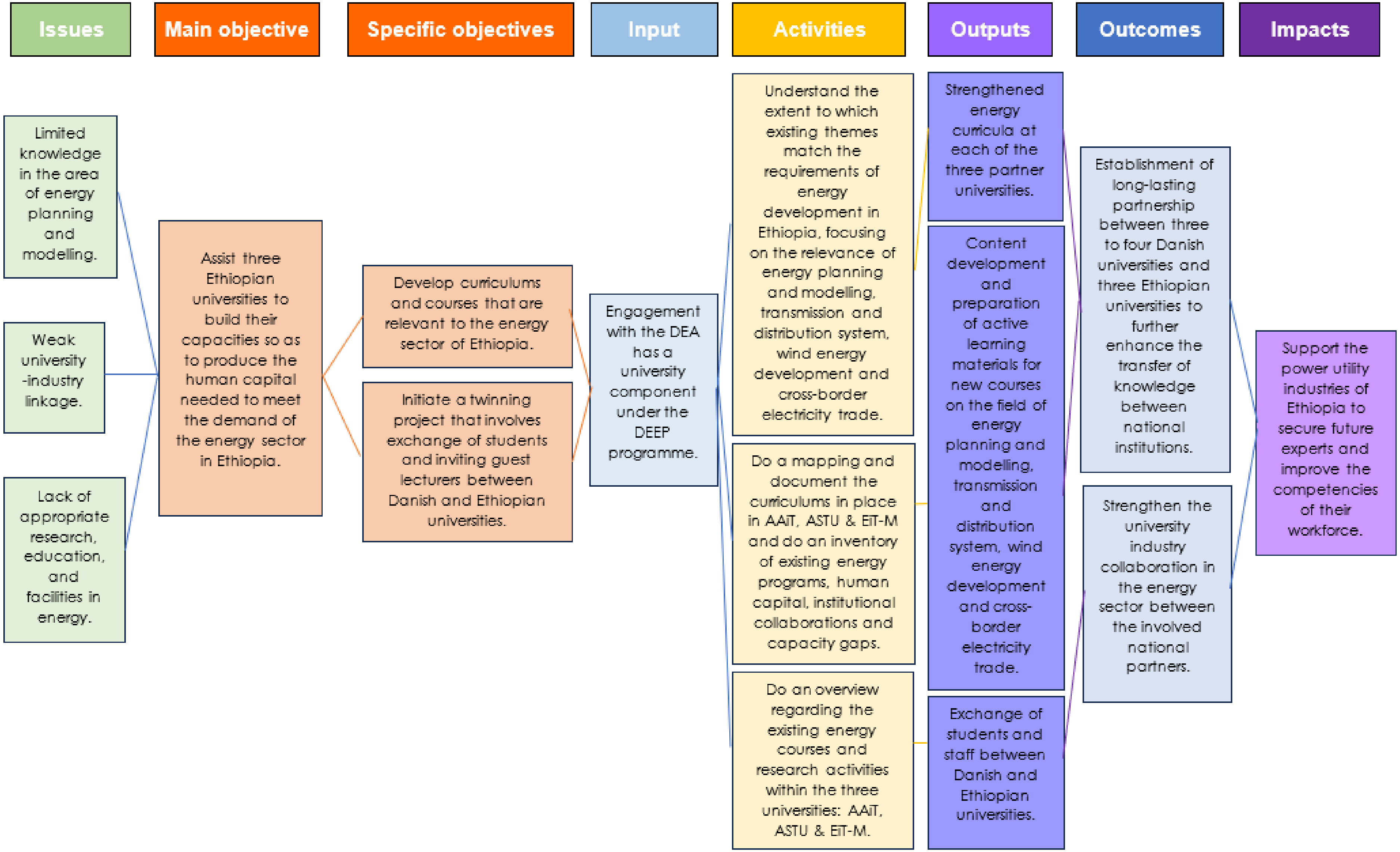

Figure 1: Reconstructed intervention logical framework of the project.

courses and compilation of course lectures, laboratory exercise and active learning materials on the fields of energy planning and modelling, transmission and distribution system, wind energy development and cross-border electricity trade is also expected to be developed as part of the output. Moreover, exchange of students and staff between Danish and Ethiopian Universities, training sessions for teachers of the three universities on the deep understanding of selected topics as well as on the teaching methods to be used in the courses will be the other outputs of the twinning project.

In general, the twining project is expected to have a positive impact by supporting the power utility industries of Ethiopia to secure future experts, improve the competencies of their workforce and create a sustainable change on the country's energy sector.

1.4. Methodology

1.4.1. Analytical approach

The mapping has followed a qualitative methodological approach with a combination of desk review, interviews and questionnaire surveys that engage all relevant stakeholders. As shown in Appendix B, two Google Forms with a list of open-ended questions and Likert scale survey questions have been prepared for utility stakeholders (MoWE, EEP, EEU, PEA, MoF, MoPD) and universities (AAiT, ASTU, EiT-M). The list of questions are based on the issues stated in the objectives and scope of the ToR. The responses from stakeholders are expected to help understand the achievements, existing barriers, human capital and capacity gaps in the Ethiopian energy sector which will in turn be useful to design effective interventions and mitigation strategies. The Likert scale questions are employed for specific issues needing measurement of the respondents' level of agreement or disagreement. List of stakeholders that were included in the survey are shown in Appendix C. Representatives of utility stakeholders are selected primarily considering their current position and relevance to the survey, which is believed to make them the right persons for the survey. On the other hand, university representatives are selected and delegated by their respective universities who have already participated in the initial discussions and meetings with the staff of the Royal Danish Embassy in June 2023.

Through recommendation by the respective organizations, it was possible to get responses from three additional representatives (i.e. in total, 15 compared to the original target 12 participants) that enhanced the quality of the study by gathering different views. Physical interviews were also part of the methodological approach primarily for the Ministry of Finance (MoF) and Ministry of Planning & Development (MoPD) while responses from the utilities and universities were mainly based on the questionnaires. The interviews were conducted based on the list of open-ended questions (see Appendix B) by trying to engage the interviewed person in the process of addressing different aspects of its organization in relation to the Ethiopian energy sector and the intention is to use the process to gather both different views and identify lessons to be learned going forward. However, due to the specific nature of the questions and for the sake of convenience, it was found that the Google Form-based questionnaires were more applicable and effective in this study.

1.4.2. Survey schedule

The factual documents, plurality of views and different project stakeholders have been consulted after the inception phase based on desk review, interviews and Google Form questionnaires during the period 5th – 16th June 2024. The input has been analysed and the mapping has been finalised from the 17th of June to the 3rd of July 2024. The report has been confirmed by stakeholders' feedback [via e-mail submission] during 22nd – 31st October, 2024.

2. Data collection and analysis

2.1. Energy stakeholders

Historically, the Ethiopian power sector has been operated and strictly regulated by a vertically integrated state-owned utility Ethiopian Electric Power Corporation (EEPCo). Its range of activities ranged from generation and power planning to transport and distribution. The unbundling process of the electricity market started in 2013 when EEPCo was split into two entities Ethiopian Electric Power (EEP) and Ethiopian Electric Utility (EEU). EEP is the sole provider of bulk electricity to users as well the responsible for generation and transmission EEU instead, owns, operates and manages electricity distribution networks. Another body was created as well - Ethiopian Energy Authority (EEA, now renamed Petroleum and Energy Authority (PEA)) with the scope of regulating the electricity and energy efficiency sectors. PEA is accountable to the Ministry of Trade and Regional Integration (MoTRI).

The Ministry of Water & Energy (MoWE) is the lead institution for the Ethiopian Energy Sector. The latest organizational diagram of the Ethiopian energy sector is represented in Figure 2 below. Within the Ministry of Finance (MoF) Public-Private Partnership Directorate General (PPP-DG) and the Public Enterprise Holding and Administration (PEHA) are established. PPP-DG endeavors to meet the growing demand of the public on service delivery and infrastructure. PEHA and the Ethiopian Investment Holdings (EIH) are supervisory bodies of various state-owned enterprises (SOEs) including EEP and EEU, respectively. The government of Ethiopia has also assigned EEP as the contracting authority and the buyer of electricity generated by Independent Power Producers (IPPs). Aiming to improve the financial health of SOEs, the Liability and Asset Management Corporation (LAMC) is responsible to address the risk of contingent liabilities of EEP and EEU, alongside a range of state-owned assets.

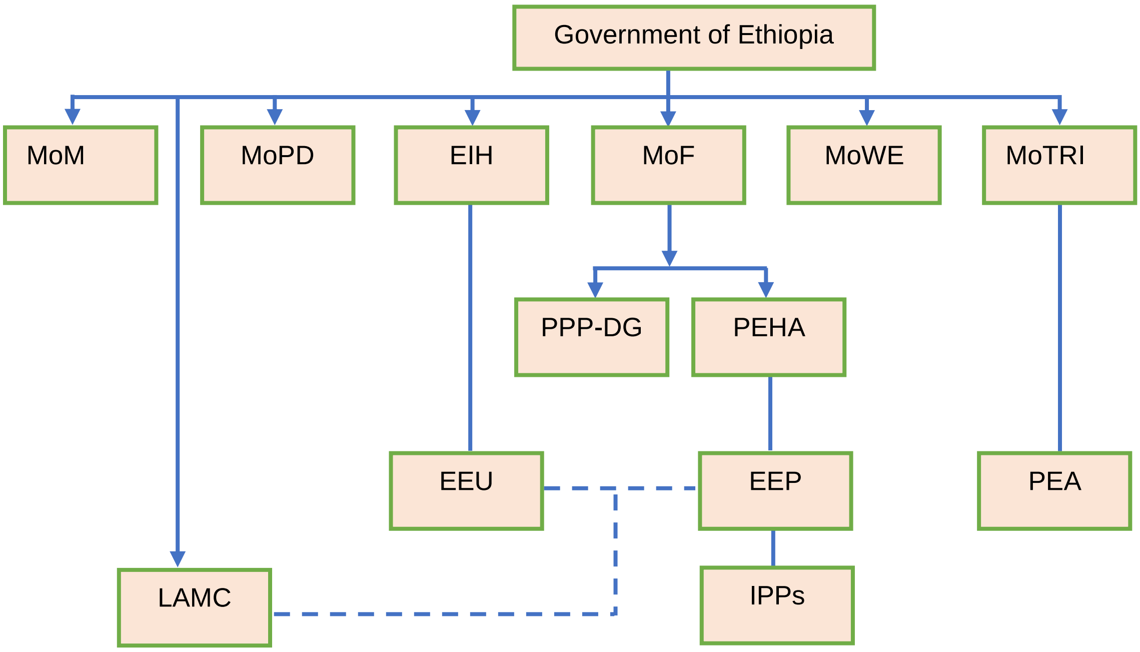

Figure 2 Current Structure in the Energy Sector

2.2. Challenges facing Ethiopian Economy and Energy Sector

The Ethiopian economy is confronted with multifaceted challenges ranging from sectoral issues such as low productivity to structural impediments such as low-skilled human resources and infrastructure gaps hindering investment and economic growth[4]. Macroeconomic challenges, including fiscal deficits, and external debt distress, threaten overall economic stability. In addition, high unemployment and inflation rates are also Ethiopia's biggest challenges. Unemployment rate for persons aged 15-29 years in urban areas of the country in 2022/23 was 27.2% while Addis Ababa registered the highest youth unemployment rate of 30%. The current government target for urban unemployment rate is 15% in 2023/24, 14% in 2024/25 and 13% in 2025/26 Ethiopian fiscal years[5]. High inflation with the general rate at about 34% in 2022 and 30% in 2023 has had a notable impact on households compared to the period between 2013 and 2017 that was characterized by a single digit non-accelerating rate of inflation. With regard to reducing inflation and cost of living pressures, the Ethiopian government is working towards achieving the target to reduce inflation rates to 20%, 12% and 8% in the years 2023/24, 2024/25 and 2025/26 respectively[5].

Public sector capability and institutional weaknesses further complicate effective policy implementation and hinder private sector development. Social challenges and the political environment, notably conflict and illegal business undertakings, add to the complexity, impacting the pursuit of inclusive and sustainable economic growth. Addressing these challenges requires comprehensive and coordinated reforms and efforts across various public organs to foster resilience, promote inclusive development and ensure Ethiopia's long-term economic sustainability.

Despite the large investments in secondary education, technical and vocational training (TVET), and higher education over the past years, the supply of highly skilled labour force is limited in Ethiopia[4]. The low-skilled labour force poses challenges to competitiveness and sustainable growth by limiting productivity and innovation. Sustainable growth relies on a workforce equipped with the quality, relevant, and practical education, skills, and knowledge necessary to adapt to changing modern technologies and contribute to a competitive and dynamic economy. Low-skilled workers resulted in lower labour productivity, hindered innovative advancements across sectors of the economy, and reduced Ethiopia's competitiveness in the global market.

To achieve sustainable growth, there is a need for transformative reform and value-for-money investments in education, training, skill, and entrepreneurship development to uplift the workforce's capabilities, ensuring their active participation and contribution to a knowledge-based and innovation-driven economy.

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[4] Medium-term Development and Investment Plan, EFY 2023/24 – 2025/26, Ministry of Planning and Development, April 2024.
[5] National Result Matrix (NRM), Ministry of Planning and Development.

2.3. Development Planning

The Government of Ethiopia (GoE) through the Ministry of Planning and Development (MoPD) has introduced its development plans through the 10-year development plan[6], medium-term development & investment plan (MDIP)[4], and national result matrix[5]. The overall development planning starts with developing a national long-term development plan that outlines the country's vision, goals, and priorities. This plan considers the overall political, social, economic, and environmental dimensions. One of the main focus areas of the development plan is to develop skilled manpower in the economic and energy sectors. Quality human resources play a crucial role in successfully implementing the planned goals by ensuring economic productivity and competitiveness. It will be difficult to implement the plans and achieve the grand goals without good quality and multi-skilled human power. The government plans stress the importance of balancing the supply of human resource with the needs of the energy and economic sectors. Given that the human resource needs in the energy sector vary in quality and quantity based on the nature of projects, it is essential to plan this ahead of time and do the necessary preparation. This plays a positive role not only in ensuring that the human resource provided by the education sector is compatible with the needs of the energy sector, thereby avoiding skills mismatch, but also in ensuring competitiveness by increasing productivity.

During the MDIP, by focusing on skills development, Ethiopia aims to address the skill gap challenge by investing in continuous learning, technical and vocational training, entrepreneurship education, reskilling and upskilling initiatives. These efforts will enhance individuals' employability, promote job creation, and contribute to reducing unemployment rates. Additionally, by promoting entrepreneurship, Ethiopia has been striving to foster a culture of innovation and create an enabling environment for businesses to thrive[4].

2.4. Diversified Green Energy

The GoE is committed to ensuring affordable, reliable, and green energy in driving sustainable, resilient, and inclusive economic growth, reducing poverty, and mitigating the impacts of climate change[4]. Ethiopia possesses abundant renewable energy resources, including hydropower, solar, geothermal, and wind energy, making the transition to green energy not only environmentally responsible but also economically viable. During the MDIP period of the EFY 2022/23 – 2025/26, several priorities and an enabling environment will be emphasized to support the strategic goal of ensuring affordable, reliable, and green energy in Ethiopia. The government recognizes the importance of energy diversification and continue sector reform, expanding the future energy mix to include renewable sources like solar, wind, and geothermal alongside traditional hydropower[4].

[4] Medium-term Development and Investment Plan, EFY 2023/24 – 2025/26, Ministry of Planning and Development, April 2024.
[5] National Result Matrix (NRM), Ministry of Planning and Development.
[6] Ten Years Development Plan – a pathway to prosperity, 2021-2030, Federal Democratic Republic of Ethiopia, Planning and Development Commission.

Ongoing reform efforts throughout the energy value chain will contribute to a future sustainable and resilient sector. Energy sector public private partnerships (PPPs) are planned to be actively pursued to mobilize additional future resources and drive the development of renewable energy projects. Collaboration with regional partners is also aimed to establish a future functional energy market and promote future energy trade.

By expanding renewable energy infrastructure, investing in decentralized energy systems, and promoting innovative energy solutions, Ethiopia can bring electricity to remote and underserved areas, empowering communities and fostering inclusive development. Off-grid solutions, such as future mini-grids and standalone solar systems, will address future energy poverty and enable future universal energy access. Equitable access to future affordable and reliable electricity services is prioritised by fostering a competitive energy market and empowering future subnational governments. Administrative reform and future project optimisation will contribute to the effective execution of energy projects in the future. By creating a future enabling environment through these measures, Ethiopia aims to achieve its energy sector's future MDIP development targets, driving future sustainable and inclusive energy sector growth and future universal access to electricity for all citizens.

The MDIP contains strategic goals, core strategic activities, and key performance indicators which are primarily associated with the Ministry of Water and Energy. The effective attainment of the strategic goal and expected results require well-coordinated roles and functions with the state-owned enterprises of Ethiopian Electric Power and Ethiopian Electric Utility.

The Ministry of Finance plays a vital role in providing financial support and ensuring the availability of mobilising resources for energy sector development through strengthening partnerships. By coordinating with the Ministry of Water and Energy, the Ministry of Finance ensures that adequate financial resources are allocated to implement energy projects, including expanding renewable energy infrastructure and enhancing energy access.

2.5. Universities

2.5.1. Energy education

Energy-education being at its evolutionary stage and a host of new energy–economy–environment nexus being identified and understood, it is somewhat difficult to define and specify the desirable features of an energy-education programme in a comprehensive manner. However, Energy education looks at energy through the lens of natural science as well as social science. Energy issues require an understanding of civics, history, economics, sociology, psychology, and politics in addition to science, technology, engineering and mathematics. A comprehensive study of energy and curriculum designed using Energy Education should be interdisciplinary and use a systems-based approach to fully appreciate the complexities of energy issues. As can be seen in Table 1, energy education programmes can generally be classified in a variety of ways depending upon the attribute used. The energy-education programmes for the general public, primary-school level and secondary-school level will, of necessity, be quite different from the university-level energy-education programmes which aim to provide in-depth theoretical knowledge of various energy technologies and systems, besides providing practical hands-on skills, training in design, fabrication, installation and maintenance. The energy-education programmes may also be categorized on the basis of the expected job responsibilities of the student/trainee. Thus, the content and emphasis of energy programmes for technicians and mechanics may be quite different from those programmes meant for researchers/engineers/policy makers. Similarly, the mode of education intended to be used also affects the energy-education programmes. For example, the techniques used in non-formal education may necessitate restructuring of the scope, content and coverage of an energy-education programme from those which adopt a more formal mode of education. The duration (short term/long term) and geographical area covered (national, regional, international) may also affect the inputs given in an energy-education programme[7].

Table 1 General classification of energy-education programmes[7]

No.	Attribute for classification	Classification of Energy Education Programmes
1.	Target groups	Fresh students, professionals already in workforce, common public.
2.	Level	Primary, secondary, undergraduate, postgraduate.
3.	Skill	Researcher, engineer, technician, mechanic.
4.	Mode	Formal, non-formal.

The three universities (i.e. AAiT, ASTU & EiT-M) are all technology academic institutions that teach and do research on energy issues by giving emphasis on science, technology, engineering and mathematics. In this regard, their energy-education programmes are expected to at-least incorporate the following features: 1) it should include all energy resources (renewable and non-renewable) extraction/generation/conversion/transportation/utilization with particular emphasis on some specific ones depending upon the local availability needs and characteristics 2) it should cover all aspects of energy technologies such as resource assessment, technology, engineering design, system operation and management, economics and energetics, sociocultural issues, ecological and environmental impacts, energy conservation, energy efficiency, techno-economic planning.

[7] T.C Kandpal, H.P Garg, Energy education, Applied Energy, Volume 64, Issues 1–4, 1999, P. 71-78, ISSN 0306-2619, https://doi.org/10.1016/S0306-2619(99)00076-8.

2.5.2. Addis Ababa Institute of Technology (AAiT)

2.5.2.1. Institution Profile[8]

Addis Ababa Institute of Technology (AAiT) is the new name for the first institution teaching engineering education and the leading Institute of Technology in Ethiopia. AAiT is under the umbrella of Addis Ababa University (AAU) which recently gained the first independent, autonomous-chartered university establishment in Ethiopia. AAU has 10 colleges, 4 institutes including AAiT and 6 research institutes.

Initially, AAiT was named the Imperial College of Engineering. It was established in 1953. In the beginning, the college opened two-year intermediate engineering programs. Subsequently, the students were sent abroad for further study leading to a B.Sc. degree. In 1958, a four-year degree program in civil and industrial engineering was launched. In the following year, the industrial engineering program was split into electrical and mechanical engineering programs, and the duration of the study for all programs was extended to five years. In 1961, the college became a chartered member of Addis Ababa University.

To effectively manage the large student population and swiftly respond to the need of the government's transformational plan and support the growth and competitiveness of the industry, the Faculty of Technology was given autonomy and new leadership with international experience since April 2010. The Faculty of Technology was re-organized into Addis Ababa Institute of Technology and the leader of the Institute is named as Scientific Director, with Vice President Status of the university. The new institute was officially inaugurated in October 2010.

The institute is the largest engineering institute with a better staff profile as compared to the other thirty-two public universities in the nation. For young PhD holders and researchers returning from abroad, it is a very preferred environment to work in. It does still play a critical role in supporting engineering education in most of the universities across the nation and beyond. It trains instructors of other universities and delivers courses as visiting professors in their programs. Thus, the quality of education and research at AAiT reflects the national strength and weakness in creativity, innovation, and entrepreneurial culture.

Currently, there are over 3,642 undergraduates and 1,426 postgraduates (1,180 MSc. and 246 PhD) students enrolled in the various programs of the Institute. The Institute has about 400 academic staff (106 Assistant Professors and above, more than 30 Visiting and part-time Professors) and about 530 administrative and support staff. As shown in Table 2, AAiT has different streams/chairs under each of the Schools. A chair is the smallest organizational component within AAiT in which academic teaching and research is given shape. The idea of setting-up these streams was to permit professionally oriented graduates to evaluate the applicability of new research findings

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[8] History of AAiT is directly taken from the "About AAiT", Addis Ababa Institute of Technology website, http://www.aait.edu.et/about-aait, [accessed: May 2024].

to prepare them for professional practice and in particular to prepare them to contribute dynamically to the development of the country. Furthermore, the stream/chair group is expected to engage in different national and international research with specific area of expertise. Each chair group is led by a Professor to conduct research in the specific domain. There is no allocated budget to these chairs, instead they are expected to bring funding by writing proposals to national and international grants, engage in industry sponsored-industry tailored training programs, provide short-term trainings, do consultancy and testing services, etc. It is rare to see long-term research collaborations that are financed by the industry. The Electrical Power Engineering Chair is under the School of Electrical and Computer Engineering which has more than 15 staffs (8 Assistant Professors and above, 1 Visiting Professor, 6 PhD candidates).

Table 2: Existing academic programs in AAiT

Academic Unit	UG	MSc	PhD
School of Civil and Environmental Engineering (SCEE)	1	11	8
School of Electrical and Computer Engineering (SECE)	1 (5 streams)	7	5
School of Mechanical and Industrial Engineering (SMIE)	1	7	3
School of Chemical and Bio Engineering (SCBE)	1 (2 streams)	6	3
School of Information Technology and Engineering (SITE)	1 (4 streams)	6	1
Center of Biomedical Engineering	1	2	2
African Railway Center of Excellence	-	3	1
Center for Materials Engineering	-	1	-
Center for Renewable Energy Technology (CRE)	-	1	-
Center of Ethio-Mines Development	-	2	-
Total	**6**	**46**	**23**

2.5.2.2. Industry-tailored Programs

In addition to the regular programs, AAiT also runs various industry-tailored postgraduate programs. The programs are designed to train the staff of the industries with relevant course works and a very effective final thesis output on specific problems that are focused on the particular needs of the industries.

The existing industry-tailored Masters programs include the following national institutions from different sectors:

- Ethiopian Roads Administration, Construction industry (two-phases, 1250+625 students),
- Ethio-telecom, 300 students -Ethio-telecom staff,
- Road Transport Safety, 25 students,
- Information Network Security Administration (INSA), Cyber Security & AI, 300 students,
- Ethiopian Railway Corporation, Railway industry, more than 325 students,
- Ministry of Mines, Mineral Technology, Petroleum Engineering,
- Sugar Corporation, Mechanical/Control Engineering,

- Metal Industry Development Institute.

Regarding industry-tailored programs, AAiT through the School of Electrical and Computer Engineering in collaboration with the former Ethiopian Electric Power Corporation (EEPCo) had trained 25 staff of EEPCo with master's degree in electrical power engineering from 2008 up to 2010. Currently, those graduates are serving EEP on top managerial and expert levels at various positions.

2.5.2.3. Research, industry-linkage and international collaboration

AAiT has been engaged in several research projects and University collaborations worldwide including energy-based projects. Some of the ongoing research projects under different grants and funding sources are listed in Table 3 below while Table 4 gives some overview of the research publications on international reputable journals. The School of Electrical and Computer Engineering has established good collaborations with foreign universities such as KTH and Chalmers (Sweden), Mihigan (USA), Toronto (Canada), Alto (Finland), Dresden (Germany), KU Leuven (Belgium), SNU (Korea), etc. by working in student and staff exchanges, delivering block courses, student advising and examination.

The SIDA-funded Ethio-Sweden PhD Program in Electrical Power and Control Engineering is an ongoing capacity-building aiming to train 13 PhD students. Swedish Universities (KTH Royal Institute of Technology and Chalmers University of Technology) are working together in running the programs in collaboration with the School of Electrical and Computer Engineering at AAiT. To ensure the relevance of research and education in the industry, Ethiopian electric utility operators (EEP &EEU) and ABB from Sweden are part of this project. EEP and EEU participate in identifying relevant research projects, availing facilities and data for researchers and contributing financial and in-kind resources as required. Similarly, ABB is to receive and supervise students (industry internship) for a period of time, up to one year. Power systems, High Voltage Engineering, Power system control, development and testing activities at ABB's facilities in Ludvika and/or *Vasteras* are to be used for this purpose. Professors in AAiT are main supervisors for all PhD candidates while KTH and Chalmers Professors are co-supervisors. PhD student supervisors and co-supervisors are to work together on student recruitment, student's work planning and progress assessment through annual meetings and continuous correspondence. The Swedish professors will also support the Ethiopian professors in supervision capacity building facilitation for training and relevant seminars. Swedish universities' professors are to support the programs by block teaching, as external examiners, and by providing research space and facilities for the PhD candidates under their supervision and their Ethiopian counterpart professors according to an agreed upon schedule during the students' study period in Sweden.

The program has accepted four students in 2019 and nine students in 2020 enrolling thirteen students over the five-year project period. Qualified female candidates were encouraged to apply and are part of the PhD candidates. Currently, three (one female) of the four students in the first batch have graduated and at the end of the project, all the 13 enrolled students are expected to graduate improving staff profile of the universities and competency of the workforce in the energy/power sector.

Furthermore, 13 dissertations and many scientific papers, which are relevant to the real challenges of the country in the power and control area are expected to be produced by the PhD candidates.

AAiT relying on its experienced and multi-disciplinary team of experts, it also engages in key national projects providing consultancy services. One notable energy project is the Adama-I Wind Farm where AAiT has been involved in supervision and commissioning works.

Table 3: Research Projects in AAiT

Title	Fund	Budget	Academic Unit
Energy Projects			
Electric Power & Control Engineering PhD Program, https://sida.aau.edu.et/index.php/electric-power-control-engineering-phd-program/	Swedish International Development Agency (SIDA)	27 million SEK	SECE
Community energy and sustainable energy transitions in East Africa (CESET), https://cesetproject.com/	The Global Challenges Research Fund (GCRF), UK	89,206 GBP	SECE
Open Modelling Toolbox for development of long-term pathways for the energy system in Africa (OpenMod4Africa) https://openmod4africa.eu/	EU Horizon-2022	51,723 EURO	SECE
Promoting Education and Research on Energy Efficient Lighting and Renewable Energy for Sustainable Development (EARLi) *https://research.aalto.fi/en/projects/promoting-education-and-research-on-energy-efficient-lighting-and*	Ministry of Foreign Affairs of Finland.	100,000 EURO	SECE
Integrated Assessment Modelling: Comprehensive and Comprehensible Science for Sustainable, Co-Created Climate Action (IAM-COMPACT), https://www.bruegel.org/iam-compact	EU Horizon-2021	30,750 EURO	CRE
Energy Technology Network (Energy Net), https://www.ntnu.edu/ept/energynet	NORAD	3,018,907 NOK	CRE
University Network on PhD Program in Energy Technology (UNET); https://www.ntnu.edu/uneterasmus	European Commission (Erasmus +)	153,000 EURO	CRE, SMIE
Energy System Development Pathways for Ethiopia (PATHWAYS). Project of three universities, UCL (UK), KTH, AAiT, https://www.ucl.ac.uk/bartlett/energy/research-projects/2023/sep/energy-system-development-pathways-ethiopia-pathways	UK Aid, Applied Research Programme on Energy and Economic Growth (EEG).	3137,765 GBP	CRE
Higher Education Partnerships in sub-Sharan Africa (HEP SSA), https://raeng.org.uk/hepssa	Anglo American Group Foundation and UK, GCRF.	200,000 GBP	SECE
Other Projects			
Consultancy of Grand Rennaisance Ethiopian Dam (GERD) hydropower plant	METEC	-	AAiT
Consultancy of Adama-I Wind Farm	EEPCo	-	AAiT
Eastern and Southern Africa Higher Education Centers of Excellence Project (ACE II) - African Railway Education and Research Institute (ARERI)	World Bank Group	6 million USD	Railway
AgroVal: Sustainable Valorization of Agro-industrial Residues Through Integration of Food, Bioproducts and Bio-energy Production;	Danish International Development Agency (DANIDA)	1,610,387 EURO	SCBE
SuCCESS 24: Sustainable Cities, Circular Economy in Sub-Saharan Africa 2024	DAAD & BMBF	400,000 EURO	SCBE
Advocating for the Strengthening of Road Traffic Legislation in Ethiopia	GRSP, IFRC	133,758 CHF	SCEE
Climate Smart Agriculture	IWMI & Bill Gate Foundation	75,000 USD	SCEE
Rice University NEST 360 Invention Education	Children Investment	75,000 USD	CBME

	Fund Foundation (CIFF)		
Development of Irrigation Standard Codes and Procedures for Ethiopia	FAO	12.8 million ETB	SCEE
Center for Industry 4.0 Technologies in Ethiopia (Ethiopie 4.0)	French Funding Agency	2.4 Million Euro	SMIE
Landslide Research Project	Ethiopian Roads Administration	48,576,500 ETB	SCEE
Developing National Productivity Norm for the Construction Sector	Ethiopian Construction Management Institute	2.4 Million ETB	SCEE
Oromia Regional Integrated Development Information Management System	Oromia Planning and Development Commission	47 Million ETB	SITE

Table 4 Overview of selected energy-related research articles by AAiT

- Dawit Habtu, Getachew Bekele, Erik O. Ahlgren, "Long-term electricity supply modelling in the context of developing countries: The OSeMOSYS-LEAP soft-linking approach for Ethiopia", Energy Strategy Reviews, Vol. 45 (2023) 101045. *https://doi.org/10.1016/j.esr.2022.101045*
- Dawit Habtu, Getachew Bekele, Erik O. Ahlgren, 2021, Energy Strategy Reviews, Vol. 36 (2021) 100671, "Long-term evolution of energy and electricity demand forecasting: The case of Ethiopia". *https://doi.org/10.1016/j.esr.2021.100671*
- Dawit Habtu, Getachew Bekele, Erik O. Ahlgren, 2020 IEEE PES/IAS PowerAfrica, Nairobi, Kenya, 2020, pp.1-5, "Energy System Modeling Tools: Review and Comparison in the Context of Developing Countries". *doi: 10.1109/PowerAfrica49420.2020.9219798*
- Dawit Habtu, Getachew Bekele, Erik O. Ahlgren, 2019 IEEE PES/IAS PowerAfrica, Abuja, Nigeria, 2019, pp. 81-86," Assessment of Resource Adequacy in Power Sector Reforms of Ethiopia". *doi: 10.1109/PowerAfrica.2019.8928820*
- Eludoyin, E. O., Broad, O., Tomei, J., Anandarajah, G., Pappis, I., Sahlberg, A., & Milligan, B. (2021). Energy system development pathways for Ethiopia: Final project report (v1.0). Zenodo. https://doi.org/10.5281/zenodo.5565165
- Dawit Habtu, Getachew Biru, Journal of Ethiopian Engineers and Architects, Zede, Vol. 35, 2017, Addis Ababa, Ethiopia, "Study on Power Distribution Network Automation to mitigate Power Outages". *https://www.ajol.info/index.php/zj/article/view/186793*
- Dires, F.G.; Amelin, M.; Bekele, G. Inflow Scenario Generation for the Ethiopian Hydropower System. *Water* 2023, *15*, 500. https://doi.org/10.3390/w15030500
- Tiruye, G.A.; Besha, A.T.; Mekonnen, Y.S.; Benti, N.E.; Gebreslase, G.A.; Tufa, R.A. Opportunities and Challenges of Renewable Energy Production in Ethiopia. *Sustainability* 2021, *13*, 10381. https://doi.org/10.3390/su131810381
- https://scholar.google.com/citations?user=AkvCsKAAAAAJ&hl=en&oi=ao

2.5.2.4. Overview of Energy Programs and courses in AAiT

Based on the investigation of the curriculums and list of programs in AAiT, standalone energy education is being given at MSc and PhD levels. However, few introductory energy-related courses are only taught at the undergraduate program in Electrical Power Engineering. These courses are: 1) Energy Conversion and Rural Electrification, and 2) Power System Planning and Management. The course - energy conversion and rural electrification aims to introduce students about the different primary energy resources and the associated technologies which are used to convert their forms into heat and electricity. This course covers both renewable and non-renewable technologies. However, much attention is given to hydropower, solar, wind, geothermal, and biomass renewable energy resources and technologies.

In the second course - power system planning and management, students learn about the fundamental of load forecasting techniques, economic dispatch and unit commitment, cost analysis of generation systems, optimal system operation, generation expansion, network expansion and planning, and HVDC transmission.

BSc Program/Stream	MSc Program	PhD Program
• Electrical Power Engineering	• Electrical Power Engineering • Renewable Energy Technology	• Electrical Power Engineering

Figure 3 Energy Programs in AAiT

Electrical Power Engineering is given at BSC, MSc and PhD programs in one of the five Chairs/Streams (i.e. Electrical Power Engineering) under the School of Electrical and Computer Engineering, while Renewable Energy Technology at MSc level is given at the Center of Renewable Energy Technology.

The Center of Renewable Energy of AAiT was established in 2009 mainly considering the multidisciplinary nature of alternative energy technologies. Graduates of this program who have different professional and academic backgrounds are expected to combine new and existing knowledge to adapt it to specific projects and situations. The relevance of the program in the Center are asserted with the development needs in renewable energy resources and project management, energy conservation and the environment, energy technology development programs, and rural energy supply. The Center is established as a principal unit to undertake energy trainings and researches emanating as an interdisciplinary platform with its own five core academic staffs and pooling affiliated faculties from other colleges and schools/centers.

The list of courses included in the MSc Program of Electrical Power Engineering at AAiT are:

Compulsory Courses

- Power System Analysis, High Voltage Engineering and Power Transient, Power System Operation and Control, Power System Quality and Reliability, Power System Planning and Management, Distributed Generation and Renewable Energy Technologies, Applied Power Electronics, Transmission and Distribution Engineering, Analytical and Computational Methods in Engineering, Research Methods, Thesis.

Elective Courses

- Modern Power System Modelling, Energy Efficient Lighting System, Digital Control Systems, Advanced Electrical Machines Analysis, Electrical Machine Design, Smart Grid, Power System Stability, Selected Topics in Electrical Power Engineering, Modern Electric Drives, Energy Conservation and the Environment, Optimal Control and Applications, Nuclear Energy, Stochastic Processes, Power System Protection, Engineering Project Planning and Management, Management Science and Operations Research.

The list of courses taught in the MSc Program of Renewable Energy Technology at AAiT are:

Compulsory Courses

- Solar Energy, Wind Energy, Bioenergy, Hydropower, Other Forms of Renewable Energy, Measurement and Instrumentation for Renewable Energy, Selected Topic in Energy, Research Methods in Engineering, Pedagogical Studies, MSc Thesis, Postgraduate Project.

Elective Courses

- Energy Conservation and the Environment, Energy Economics and Policy, Energy Project Planning and Management, Advanced Solar Thermal System, Wind Turbine and Farm Design, Photovoltaic Systems Engineering, Biomass Energy Technology, Hydro-electric Power Engineering, Modelling and Optimization of Renewable Energy System, Smart Grid.

The list of courses provided in the PhD Program of Electrical Power Engineering at AAiT are:

Compulsory Courses

- Power System Stability and Control, Modern Electric Power Systems (Part-I), Seminar on Selected Topics in Electrical Power Engineering-1, Seminar on Selected Topics in Electrical Power Engineering-2, PhD Dissertation.

Elective Courses

- Optimal Control and Applications, Computational Intelligence for Power Engineers, Power System Analysis, Advanced Electric Machinery and Drives, Modelling and Control of Complex Dynamic Systems, Power System Protection, Economic Operation of Power Systems, High Voltage Engineering, Power System Quality and Reliability, Power System Planning and Management, Modern Electric Power Systems (Part-II), Advanced Power Electronics.

2.5.2.5. List of energy Laboratories at AAiT

The UG and PG energy programs in AAiT are currently equipped with the following laboratories.

- Core laboratories (Fundamental Electrical Circuit Lab, Applied Electronics Lab, Digital Electronics Design Lab, Electrical Installation and Workshop Lab, Electrical Machines Lab, PLC and Embedded Lab, Power Electronics Lab), R&D Labs (high Voltage Lab, Power Quality Lab, Power Systems SCADA Simulation Lab, Control and Instrumentation Lab).

The core laboratories are into the science that are meant to be used by students for visualizing the theoretical concepts taught in class while R&D labs are focused to specific needs and are important for graduate students to do their course projects and thesis, In addition, various training and consultancy/testing services are provided for external clients – governmental and private industries. Considering the R&D laboratory requirement for advanced energy courses and the testing needs of various electrical products by the industry, it is important to expand the existing labs and establish new labs (e.g. Energy Systems Simulation and Modeling Lab, Lighting lab, Transformer test center, High current lab, Solar PV testing lab) for AAiT.

2.5.3. Adama Science and Technology (ASTU)

2.5.3.1. Institution Profile[9]

Adama Science and Technology University (ASTU) is found at the city of Adama in central Oromia region of Ethiopia, at a distance of 99 kilometers from Addis Ababa. ASTU is one of the two science and technology universities established to support the industrial development of the nation by producing competent and leading graduates in science and technology fields. It was first established in 1993 as Nazareth Technical College (NTC), offering degree and diploma level education in technology fields. Later, the institution was renamed as Nazareth College of Technical Teacher Education (NCTTE), a self-explanatory label that describes what the institution used to train back then: candidates who would become technical teachers for TVET colleges/Schools across the country. In 2003, a new addition to NCTTE came about—introduction of business education. Nonetheless, the new entries were solely meant for similar purposes: these graduates were also expected to help overcome the existing dearth of educators in vocational institutions. Although it is an institution with a history of only two decades, ASTU is known for its dynamic past. It has always been responsive to the realization of national policies: training of technologists at its infant stage, and later shifting to training of technical trainers, as well as business educators, to fill the gap in TVETs.

Following its inauguration in May 2006 as Adama University, the full-fledged university started opening other academic programs in other areas—an extension to its original mission. However, it was not until it was nominated by the Ministry of Education as Center of Excellence in Technology in 2008 that it opened various programs in applied engineering and technology. In addition to its main concern (academics), ASTU is also host of research Institutes and enterprises. In the main campus, apart from the Institute of Continuing and Distance Education (ICDE), there exist two others: the Further Training Institute (better known as FTI) and Adama Institute of Sustainable Energy. The sister town where the two schools are located, Asella, is also host to the Artificial Insemination Institute and Asella model Agricultural Enterprise.

Following its renaming by the Council of Ministers as Adama Science and Technology University in May 2011, the university has started working towards the attainment of becoming a center of excellence in science and technology, thereby allowing for the realization of goals set in the Growth and Transformation Plan (GTP). The university is also working aggressively to produce qualified, competent, and socially responsible professionals in the fields of science and technology through promoting research-oriented science and technology education. In addition to the regular PhD programs (see Table 5), ASTU is hosting and co-hosting Home-grown collaborative PhD programs (HCPPs) on 1) Agricultural Mechanization - Agricultural Machinery Engineering, Irrigation Engineering, Animal Biotechnology, 2) Manufacturing - Manufacturing Engineering, Power engineering, Thermal Engineering, Urban and Regional Planning, Water Supply and Sanitary Engineering, Space Science, 3) ICT – Computer Science and Engineering, Communication Engineering, Big Data, Technology and Innovation Management.

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[9] History of ASTU is directly taken from the "About ASTU", Adama Science and Technology University website, https://www.astu.edu.et/9-about-astu, [accessed: May 2024].

Unlike the chair group set-up in AAiT, ASTU has dedicated departments under different Schools (see Table 5).

Table 5: Existing academic programs in ASTU

Academic Unit	UG (Departments)	MSc	PhD
School of Civil Engineering and Architecture	8	4	2
School of Mechanical, Chemical and Materials Engineering	5	5	4
School of Electrical Engineering and Computing	4	8	7
School of Applied Natural Science	7	5	4
School of Humanities and Social Science	4	1	1
Total	**28**	**23**	**18**

2.5.3.2. Research, industry-linkage and international collaboration

Some of the projects and energy articles in ASTU are shown below in Table 6 and Table 7 respectively.

Table 6 Some research projects in ASTU

Title	Fund	Budget	Academic Unit
Energy Projects			
Standalone Solar Charging Station (SACS) for Decentralized Transportation hubs in rural Africa, ASTU, TUM, Germany/FZJ-PtJ, Stellenbosch University, https://www.leap-re.eu/2022/10/17/solchargee-field-tests-started-to-develop-e-mobility-in-sub-saharan-africa/	LEAP-RE	-	-
Other Projects			
Adama-II Wind Farm Consultancy	EEP	-	-
Solar Power System Design and its Improvement for Both Household Water Supply and Electrification Package (Sidama Region)	Ethiopian Water Technology Institute (EWTI)	-	-
Access Design and Develop Small Wind Turbine for Water Pump and Household Electrification for Small Community (Adami Tulu)	EWTI	-	-
Solar Photovoltaic System Assembly, Installation and Operation for selected 50 Households in Oromia region	-	-	-

Table 7 Overview of selected energy-related research articles by ASTU

- Birku Reta Entele, Analysis of households' willingness to pay for a renewable source of electricity service connection: evidence from a double-bounded dichotomous choice survey in rural Ethiopia, Heliyon, Volume 6, Issue 2, 2020, e03332, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2020.e03332
- Milkias Berhanu Tuka, 'Investigations of Voltage Dip Problems During Faults on a Grid-tied Doubly Fed Induction Generator with Wind Turbine System, Jordan Journal of Electrical Engineering, Volume 9 | Number 2 | June 2023, 209-227 https://doi.org/10.5455/jjee.204-1669028936
- Milkias Berhanu Tuka, Niguse Assefa Abebe, Fetlework Kedir Abdu, 'Design and Analysis of Artificial Intelligence-based Controller for Rotor Current of Doubly Fed Induction Generator in Wind Turbine System', Sage Journals, Wind Engineering Journal, 2023; doi: https://doi.org/10.1177/0309524X2311730
- Endalew Ayenew, Getachew Biru, Asrat Mulatu, Milkias Berhanu, 'Modelling and Control of Wind Energy Conversion System: Performance Enhancement', Springer, International Journal of Dynamics, 01 June 2023, https://doi.org/10.1007/s40435-023-01201-w

- Mekdes Gemechu Kebede, Milkias Berhanu Tuka, "Power Control of Wind Energy Conversion System with Doubly Fed Induction Generator", Journal of Energy, Vol. 2022, Article ID 8679053, 12 pages, 2022. https://doi.org/10.1155/2022/8679053
- Endalew Ayenew, Milkias Berhanu, 'Application of Artificial Intelligent Technique to Maximize Power Yielding Ability of Wind Turbine,' Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Taylor & Francis, Volume 44, 2022-Issue 1, https://doi.org/10.1080/15567036.2022.2058123
- Endalew Ayenew, Getachew Biru, Asrat Mulatu, Milkias Berhanu, "*Improving Power Harvesting Ability of Variable Speed Wind Turbine Using Intelligent Soft Computing Technique*", Journal on Advanced Research in Electrical Engg.,5, 1, 2021, DOI: https://doi.org/10.12962/jaree.v5i1.186
- https://scholar.google.com/scholar?start=10&q=milkias+berhanu&hl=en&as_sdt=0,5

2.5.3.3. Overview of Energy Programs and courses in ASTU

The Department of Electrical Power and Control Engineering (EPCE) is one of the three departments in School of Electrical Engineering and Computing of ASTU. The EPCE department teaches deep knowledge in basic science of Power Engineering and Control systems. Electrical Power Engineering is given at BSc, MSc and PhD programs under the School of Electrical Engineering and Computing. Currently, there are over 200 undergraduates and 123 postgraduates (116 MSc and 7 PhD) students enrolled in the EPCE department. The department has 44 teaching academic staffs on duties in which 11 have the rank of Assistant Professor and above with 7 PhD candidates on study leaves.

Based on the investigation of the curriculums and list of programs in ASTU, standalone energy education is being given at MSc and PhD levels. At the UG level, introductory energy courses are taught in the Electrical Power and Control Engineering program. These courses are: 1) Energy Conversion Engineering, and 2) Electrical Power Transmission and Distribution Engineering, 3) Energy Management and Auditing, 4) Power System Planning and Operation and 5) Distribution Generation and Microgrids.

BSc Program	MSc Program	PhD Program
• Electrical Power and Control Engineering	• Power Systems Engineering	• Electrical Engineering

Figure 4 Energy Programs in ASTU

The list of courses included in the MSc Program of Power Systems Engineering at ASTU are:

Compulsory Courses

- Advanced Power Systems Analysis, Power System Dynamics and Stability, Advanced Power Electronics in Power Systems, Modelling and Control of Electrical Machines, High Voltage Engineering and Transients, Scientific Research Methods and Ethics, Linear and Nonlinear Systems Theory, Independent Project on Recent Topics of Research area, Thesis.

Elective Courses

- Distribution System Planning and Automation, Advanced Power System Operation and Control, Power Systems Computation Lab, HVDC Transmission, Smart Grid Design and Analysis, Advanced Power Systems Modeling, Flexible AC Transmission Systems, Optimization

Techniques in Power Systems, Power Supply Quality and Reliability, Realtime Control of Power Systems and Energy Management, Digital Protection of Power Systems.

The list of courses included in the PhD Program of Electrical Engineering at ASTU are:

Compulsory Courses

- Scientific Research Methods and Ethics, Smart Grid Technology, PhD Dissertation Proposal, PhD Dissertation,

Elective Courses

- Computer Methods in Power System, Transmission Systems Engineering, Power Distribution Engineering, Advanced Power System Protection System, Artificial Intelligence, Electrical Machine Design, Optimization Methods, Postgraduate courses from MSc programmes.

2.5.3.4. List of energy Laboratories at ASTU

The energy programs in ASTU are currently equipped with laboratories comprising of the following independent sections:

- Basic Electrical Engineering Laboratory, Electrical Installation and workshop Laboratory, Electrical Machines Laboratory, Power System Laboratory, Power Electronics Laboratory, PLC and Embedded Automation Laboratory.

Nevertheless, for PG program ASTU aspires to establish future laboratories for special experimental and research works as listed below.

- Transformers tests laboratory, Protective relaying and distribution automation laboratory, Protective relaying and distribution automation laboratory, Power system modeling & simulation tools, High voltage test laboratory, Embedded system laboratory, Instrumentation laboratory, Industrial automation laboratory, DSP based electric drive laboratory.

2.5.4. Ethiopian Institute of Technology-Mekelle (EiT-M)

2.5.4.1. Institution Profile[10]

The Ethiopian Institute of Technology-Mekelle (EiT-M) (initially named as the Faculty of Science and Technology and later renamed as College of Engineering) is found in Mekelle, Tigray region of Northern Ethiopia, at a distance of 783 kilometers from the Ethiopian capital. EiT-M is one of the eleven institutes under Mekelle University (MU). Mekelle University was formed by merging the two former colleges: Mekelle Business College and Mekelle University College in the year 2000. MU is now one of Ethiopia's Centers of Excellence in Research and Education with colleges of diversified fields of areas situated in the different parts of Mekelle and the surroundings.

The EiT-M comprises different schools and departments including School of Mechanical and Industrial Engineering, School of Architecture and Urban Planning, School of Civil Engineering, School of Electrical and Computer Engineering, School of Computer Science and Information Systems, Department of Chemical Engineering,

[10] Profile of EiT-M is directly taken from the "About EiT-M", Ethiopian Institute of Technology-Mekelle website, https://www.mu.edu.et/index.php/ethiopian-institute-of-technology-mekelle-eit-m, [accessed: May 2024].

and Department of Garment and Textile Engineering. Similar to the chair group set-up in AAiT, EiT-M also comprises various streams under different Schools (see Table 8).

Table 8: Existing academic programs in EiT-M

Academic Unit	UG	MSc	PhD
School of Mechanical and Industrial Engineering	1 (5 streams)	10	4
School of Architecture and Urban Planning	1 (2 streams)	3	
School of Civil Engineering	1 (3 streams)	6	1
School of Electrical and Computer Engineering	1 (5 streams)	6	
School of Computer Science and Information Systems	1	1	
Department of Chemical Engineering	1 (3 streams)	2	
Department of Garment and Textile Engineering	1		
Total	**7**	**28**	**5**

2.5.4.2. Research, industry-linkage and international collaboration

EiT-M, through the School of Mechanical and Industrial Engineering is engaged in a number of international academic and research collaborations. These include: through the Norad program with in Energy and Petroleum (EnPe-I and EnPe-II) projects, NOMA projects, the NORAD III and IV projects, through the Inter-University Cooperation of Belgium (MU-IUC), College of Agriculture of the Kansas state (USA) project, KTH (Sweden) project through distance education in sustainable energy engineering focusing on energy. These collaborations have resulted in various renewable energy projects such as: solar energy assessment, solar cookers, solar driers, solar water heater and PV, solar autoclave, solar injera baking stove, solar stills, solar oil extractor, wind resource assessment, wind masts, wind pump, small-scale wind turbines, biogas digester, biogas stove, biogas injera baking system, gasifier stove, etc.

Some of the ongoing research projects under different grants and funding sources are listed in Table 9 below while Table 10 gives some overview of the research publications on international reputable journals.

Table 9 Some research Projects in EiT-M

Title	Fund	Budget	Academic Unit
Community energy and sustainable energy transitions in East Africa (CESET), https://cesetproject.com/	The Global Challenges Research Fund (GCRF), UK	100,897 GBP	Center of Energy
Strengthening Mobility and Promoting Regional Integration of Engineering Education in Africa (SPREE)	Intra-Africa scheme, European union	278,595 EURO	Center of Energy
Applied Curricula in Technology for East Africa (ACTEA)	Erasmus+ European Union	86,000 EURO	Center of Energy
EDUTEX-Knitting Together Africa and Europe	DAAD, Germany	130,000 EURO	Center of Energy
Transforming Energy Access-Learning partnership	DfiD & UKAID through Carbon Trust, UK	38,559 GBP	Center of Energy
Energy Auditing for the Implementation of Evidence Based Conservation Measures: The Case of MAA Garment	GIZ, Ethiopia	19,280 EURO	Center of Energy
Establishment of Center of Excellence in Renewable Energy with Focus on Solar and Wind energy	KfW	2,350,000 EURO	Center of Energy
Other Projects			

EnPe I EnPe2010-2014 – Norwegian Programme for Capacity building Development in Higher Education and Research for Development within the Fields of Energy and Petroleum	-	-	-
NOMA project NOMAPRO-2006/2012 Norwegian Programme for Master program in Renewable Energy	-	-	-
NUFU project NUFUPRO-2007/2012 Norwegian Programme for Small scale Concentrating Solar Energy	-	-	-
NORAD III project Norwegian Agency for Development Cooperation (Norad-III)	-	-	-
NORAD IV project Norwegian Agency for Development Cooperation (Norad-IV)	-	-	-
MU-IUC project Mekelle University/Inter-University Cooperation of Belgium	-	-	-
NARF project National Agricultural Research Fund project	-	-	-
University Network on PhD program in Energy Technology project (UNET) Funded by ERASMUS +	-	-	-
Energy Technology Network Project (ENET) funded by NORHE II	-	-	-
Grants to Support the Initiation of International Collaboration on Solar energy research	-	-	-
Carnot GEN-Sets -Feasibility study	-	-	-
Opportunities and Challenges of Development and Implementation of Distributed Energy Generation Systems in Ethiopia: The Case of Tigray Region	-	-	-
Consultancy for Assessment on Energy access, use, needs, markets and challenges in Shire refugee camps	-	-	-

Table 10 Overview of selected energy-related research articles by EiT-M

- Mulualem G. Gebreslassie, Solomon T. Bahta, Yacob Mulugetta, Tsegay T. Mezgebe, Hailekiros Sibhato, The need to localize energy technologies for Africa's post COVID-19 recovery and growth, Scientific African, Volume 19, 2023, e01488, ISSN 2468-2276, https://doi.org/10.1016/j.sciaf.2022.e01488.
- Mulugetta, Y., Sokona, Y., Trotter, P.A. *et al.* Africa needs context-relevant evidence to shape its clean energy future. *Nat Energy* 7, 1015–1022 (2022). https://doi.org/10.1038/s41560-022-01152-0.
- Gebreslassie, M.G., Cuvilas, C., Zalengera, C. *et al.* Delivering an off-grid transition to sustainable energy in Ethiopia and Mozambique. *Energ Sustain Soc* 12, 23 (2022). https://doi.org/10.1186/s13705-022-00348-2
- Comparative assessment of the challenges faced by the solar energy industry in Ethiopia before and during the COVID-19 pandemic, WIREs Energy and Environment, Volume 11, Issue 2, e418, https://doi.org/10.1002/wene.418
- Mulualem G. Gebreslassie, Development and manufacturing of solar and wind energy technologies in Ethiopia: Challenges and policy implications, Renewable Energy, Volume 168, 2021, Pages 107-118, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2020.11.042
- https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=mulualem+gebregiorgis+gebreslassie&btnG=&oq=Mulualem+Gebregiorgis+

2.5.4.3. Overview of Energy Programs and courses in EiT-M

EiT-M is running a Postgraduate (PG) program in Energy Technology at the Thermal and Energy Systems Chair in the School of Mechanical and Industrial Engineering, which is entirely focusing on energy. Electrical Power Engineering and Sustainable Energy Engineering programs are given at MSc level and dedicated PhD program in Energy. It also runs PG programs in Thermo-Fluid Engineering, which has a curriculum that moderately incorporates energy applications, both at course work and research levels. Currently, there are over 300 undergraduate students in Mechanical Engineering and Electrical Engineering programs of the institute while number of postgraduate students enrolled in PG programs are 25 in MSc in Electrical Power Engineering, 8 in MSc in Sustainable Energy Engineering, 11 in MSc in Thermo-Fluid Engineering and 12 PhD in Energy.

Based on the investigation of the curriculums and list of programs in EiT-M, standalone energy education is being given at MSc and PhD levels. At the UG level, introductory energy-related courses are taught in Electrical Power Engineering and Thermal and Energy System Engineering programs. These courses are: 1) Energy Conversion and Rural Electrification, 2) Power System Planning and Operation, 3) Hydropower Engineering, 4) Design of Renewable Energy Systems and 5) Power Plant Engineering. The course – design of renewable energy systems aims to provide students the practical knowledge that will enable them to fit in the workplace relatively easy. Learning outcomes include understanding the concepts and applications of various technologies; apply engineering fundamentals in calculation related to energy systems; design, manufacture and test appropriate energy technologies and evaluate their performances. In the other course – Power Plant Engineering, students learn about the energy resources and energy systems available for the production of power; analyze the efficient and output of modern Rankine cycle steam power plants with superheat, reheat, regeneration, and irreversibilities; principles of operations, components and applications of steam turbines, steam generations, condensers, feed water and circulating water systems; indicators of financial performance and economics of power generators.

BSc Program/Streams	MSc Program	PhD Program
• Electrical Power Engineering • Thermal System Engineering • Renewable Energy	• Electrical Power Engineering • Sustainable Energy Engineering • Thermo-Fluid Engineering	• Energy

Figure 5 Energy Programs in EiT-M

In terms of human capacity, EiT-M has more than 30 academic staff (20 Assistant Professors and above, 10 Lecturers) who have specialized in the field of energy.

The list of courses included in the MSc Program of Electrical Power Engineering at EiT-M are:

Compulsory Courses

- Advanced Power System Analysis, High Voltage Engineering, Distribution System Engineering, Advanced Power System Operation and Control, Power System Protection, Advanced Power Electronics and Utility Application, Renewable Power Generation Technology, Power System Planning and Management, Analytical and Computational Methods, Postgraduate Seminar, Thesis.

Elective Courses

- Power System Quality, Advanced Electrical Machine Design, Linear and Non-Linear Systems Theory.

The list of courses included in the MSc Program of Sustainable Energy Engineering at EiT-M are:

Compulsory Courses

- Introduction to Energy, Computational Fluid Dynamics and Heat Transfer, Energy Conservation and Management, Energy Economics and Policy, Research Methods and Seminar, Solar Energy, Bioenergy, Wind Energy, Hydro Energy, Alternative Energies, Off-grid Energy Systems, Modelling and Simulation in Energy Technology, Hybrid Energy Systems, Experimental Methods for Engineers, Laboratory, Master Thesis.

Elective Courses

- Thermal System Design, System Integration Project, Energy for Sustainable Development.

The list of courses included in the MSc Program of Thermo-Fluid Engineering at EiT-M are:

Compulsory Courses

- Advanced Engineering Mathematics, Advanced Fluid Mechanics, Advanced Thermodynamics, Advanced Heat and Mass Transfer, Energy Conservation and Waste Heat Recovery, Advanced Refrigeration & Air Conditioning, Computational Fluid Dynamics & Heat Transfer, Combustion Engineering, Design of Thermal Systems, Design of Fluid Engineering Systems, Gas Dynamics and Jet Propulsion, Research Methodology & Seminar, Thermo-Fluid Lab, Master Thesis.

Elective Courses

- Advanced Internal Combustion Engines, Thermal Hydraulics in Power Generation Technology, Radiative Heat Transfer in Participating Media, Heat & Fluid in Porous Media, Numerical Simulation and Modeling of Turbulent Flows, Two-phase Flow & Heat Transfer, Gas Turbine Theory, Hydropower Plant, Principles of Hydraulics & Pneumatics, Viscous Fluid Flow.

The list of courses included in the PhD Program of Energy at EiT-M are:

Compulsory Courses

- Research Methodology, Experimental Methods, PhD Dissertation.

Elective Courses

- Hydropower Plants: Selected Interdisciplinary Topics, Frequency and Power Governing of Hydropower Plants, Bioenergy: Technology and System, Biofuels and Biorefineries, Magnetic Design of Permanent Magnet Machines, Power System Stability and Control, Digital Signal Processing in Power Electronic Systems, Numerical Optimal Control, Postgraduate courses from MSc programmes, Aerodynamics, Life Cycle Assessment, Wind Turbine Design, Solar Thermal Engineering, Solar Photovoltaic.

2.5.4.4. List of energy Laboratories at EiT-M

The existing laboratories in EiT-M that are utilized for the purpose of running the UG and PG energy programs are the following.

- Power Engineering labs, Electrical machines lab, Thermal system labs, Fluid-turbo machinery labs, Wind & Solar energy technologies demonstration centre, Hydraulics and Pumped storage lab, Bio energy lab.

In addition, EiT-M has ordered a high tech solar and wind laboratory worth 650,000 Euro with the help of funding from KfW to support the research activities of the PhD program in Energy.

2.5.5. Summary of Energy Programs in AAiT, ASTU and EiT-M

Considering the detail descriptions of the energy programs in preceding sections, Table 11 below summarizes the existing energy programs in both undergraduate and postgraduate levels for the three universities.

Table 11 Summary of Energy Programs in AAiT, ASTU and EiT-M

Programmes	AAiT	ASTU	EiT-M
BSc	-Electrical Power Engineering	-Electrical Power and Control Engineering	-Electrical Power Engineering -Thermal System Engineering -Renewable Energy
MSc	-Electrical Power Engineering -Renewable Energy Technology	-Power Systems Engineering	-Electrical Power Engineering -Sustainable Energy Engineering -Thermo-Fluid Engineering
PhD	-Electrical Power Engineering	-Electrical Engineering	-Energy
Industry-tailored energy programs	MSc in Electrical Power Engineering in collaboration with the former Ethiopian Electric Power Corporation (EEPCo). **Remark**: 25 staff of EEPCo were trained with Master's degree from 2008 up to 2010. Currently, those graduates are serving EEP on top managerial and expert levels at various positions. Ongoing discussion between AAiT & EEP to restart the program.	N/A	MSc in Thermo-Fluids Engineering in collaboration with Mesfin Industrial Engineering. **Remark**: The programme has been running smoothly for years but had ceased operations during the last three years due to the war. The programme will soon be revived and will continue providing training for the industry employees.
Other relevant characteristics	Few introductory energy-related courses are only taught at the undergraduate program in Electrical Power Engineering. These courses are: 1) Energy Conversion and Rural Electrification, and 2) Power System Planning and Management.	At the UG level, introductory energy courses are taught in the Electrical Power and Control Engineering program. These courses are: 1) Energy Conversion Engineering, and 2) Electrical Power Transmission and Distribution Engineering, 3) Energy Management and Auditing, 4) Power System Planning and Operation and 5) Distribution Generation and Microgrids.	At the UG level, introductory energy-related courses are taught in Electrical Power Engineering and Thermal and Energy System Engineering programs. These courses are: 1) Energy Conversion and Rural Electrification, 2) Power System Planning and Operation, 3) Hydropower Engineering, 4) Design of Renewable Energy Systems and 5) Power Plant Engineering.

2.6. Survey Findings

2.6.1. Utility Stakeholders

Table 12 Capabilities, barriers and action options in Utility Stakeholder Institutions

Questions	Ministries (MoWE, MoPD, MoF)	Utilities (EEP, EEU, EPEA)
Main priority areas or themes of the energy/power sector in Ethiopia.	• Ensuring universal electricity access. • Renewable energy (hydro, solar, wind) development, Affordable and energy access for all, PPP.	• Renewable energy integration (mainly hydro), Energy access, Energy efficiency, Modernized/digitized energy sector, Development of skilled HR, Cost-effectiveness, Energy economics, Loss reduction, Off-grid/decentralized power generation system, Integrated energy planning, Security/reliability of supply.
Field of expertise relevancy level • Energy Planning and Modelling • Transmission and distribution system • Wind energy development • Cross-border electricity trade • Others?	• Highly relevant • Highly relevant • Highly relevant • Highly relevant • Creating enabling environment for deregulated energy market, participation of the private sector in the Ethiopian energy market, Policy and regulatory infrastructure for IPP/PPP, Solar energy, Hydropower energy, PPP.	• Highly relevant • Highly relevant • Somewhat relevant • Highly relevant • HVDC system, Smart grid, SCADA/EMS, Certification programs for engineers & technicians, Energy efficiency & conservation, Demand-side management, Market development, Economic regulation, Energy policy, Regulatory frameworks, Energy Economics, Power Economics, Intermittent energy source modelling & variation management, Water value, Power to X (PtX),
Extent of the current level of skills and knowledge Vs what is required for energy development in Ethiopia.	• The Ethiopian energy sector is undergoing reforms, and sooner or later there is going to be significant role to be played by private investment in all value chain of the power sector; and the staff in MoWE, EEP, EEU, PEA and other relevant institutions should be equipped with the relevant knowledge that could help them entertain these dynamics. • Energy sector planning requires decision-making based on evidence-based scientific studies. This requires skilled energy planners with deep knowledge of energy modelling and analysis techniques. HR development of the energy sector also requires strong coordination between various actors. In light of all these, the current level of skills and knowledge do not match the Ethiopian energy development	• Recent assessments showed that there is a higher need to bridge the skill-gap through various kinds of capacity-building & on-job trainings in energy planning & modelling, strategy development, monitoring & evaluation, project impact assessment. • Including international certified training programs that can support professional development by certifying employees. • Curriculum revisions to encompass areas such as energy policy, regulatory frameworks, demand-side management. • Specialized independent courses such as energy economics and power economics should be added considering the sectoral reform is on the verge of realization. Additionally, fostering interdisciplinary collaboration

	which in turn affect the quality of planning and growth of the sector.	with departments like environmental science and economics would provide a well-rounded education reflective of the multifaceted nature of energy planning.
Examples of achievements in terms of advancing the themes:	• Setting broader frame for the energy sector in the national plans.	• Collaborated with Danish Fellowship program to train staff. • Enrolled more than 30 leaders on the "Project management professionals" certification program. • Development of regulatory frameworks to support identified thematic areas. • Advancing energy forecasting by implementing ERP SAP forecasting module.
• Energy Planning and Modelling	• MoWE is working in partnership with the Danish government, under the DEEP program to help build planning capabilities of professionals and similar initiatives are being run by other development partners in the form of technical assistance to advance the capabilities of our professionals and professionals of other sector institutions as well.	• Contributed to the Master plan using different modeling tools. • Ensure cost-effective sector development & investment through least-cost planning. • Adopted various tools/software that would assist the energy planning and modelling. • Partnership programs have been placed to capacitate employees in energy planning and modelling tools such as: BALMOREL with partners like Danida fellowship.
• Transmission and distribution system	• Allocated significant resource to both - transmission and distribution through SoE's instead of focusing only on generation. • Regular follow-up of the performance of transmission and distribution systems.	• Various modernization programs put in place to modernize the transmission system. • Intensive investment has been allotted to expand the transmission grid including connecting with neighboring countries. • National transmission and distribution grid code are defined, safety and clearance codes are defined, investment permits and operation license are issued.
• Wind energy development	• Alternative energy sources like wind energy have been prioritized in the national plan. • In the Danish program - the DEEP, MoWE is trying to capacitate the analytical knowledge of its experts so that they will be engaged in the energy resource assessment studies including master planning for wind resources, feasibility studies, etc	• Guidelines for wind energy development and issuance of investment permit, wind PPA approval guidelines, renewable energy and wind powerplant grid-connection procedure. • With the aim of enhancing the energy-mix, huge investment has been done to construct wind powerplants. • Long-term PPA agreement for exporting electric power to

• Cross-border electricity trade	• Energy-export has been prioritized as one of the national agenda. • Not done much and capacity building in this area is primarily needed (e.g. dynamic trading, day-ahead market, etc.).	Sudan, Kenya and Djibouti. Ongoing agreement with Tanzania and searching other power markets. Moreover, the day-ahead energy market anticipated through EAPP is maturing enough to be operational by 2025. • Grid-code development, licensing framework for cross-border electricity trade, PPA approval guidelines.
• Others	• Public financing of the GERD.	• Profound knowledge and experience in the generation and transmission business, Dependable power generation capacity, Increased grid power transformation capacity, Existing initiatives for operational excellence, Employee dedication to organization mission, Increasing access for regional market share, Short and long-term development plan. • Regulatory framework, particularly legal & economic regulations such as tariff are in place. Energy efficiency policy and strategy is developed nationally as well as sector wise. Achievements are registered in ensuring Energy conservation. • Expansion of AMI meters across all demand categories and bill payment through digital platforms.
Existing barriers or challenges in relation to advancing the themes	• Significant financing demand to address the backlogs as well as lack of cost effective and viable and innovative off grid energy projects and actors. • Distribution and transmission losses, power interruption due to inefficiency of the sector. • Despite the government push and attempt to open-up the energy sector for private firms, the private-sector has not flourished enough and not many companies are expanding as required. The public sector is also limited to absorb university graduates.	• Strategic thinking & leadership, corporate culture & employee engagement, energy security & grid reliability. • Huge capacity limitations (financial issues to address them), old infrastructure, limited expansion, lack of awareness. • Less capability of professionals on modeling. • Energy loss, lack of energy planning and modeling, lack of appropriate staff in energy economics, demand side management, aged distribution networks, unreliable energy supply, lack of cost reflective tariff, poor project management, lack of appropriate and modern technology implementation. • Gender disparity in the energy sector (i.e. low percentage of female employees in engineering fields and the need for female faculties and researchers)

Furthering education, training or competence development strategies to meet the demand of the energy sector in Ethiopia.	• Analytical capability should sustainably be built - the sector really needs specialists, energy modelers, energy system analysts. To create those professionals, short-term trainings are important; but, on top of that curricula needs to be created/revised in the academia containing those themes so that it is possible to ensure availability of sustained knowledge in the sector. • Private sector engagement should be realized including academies institutions, the government should follow diversified energy sources, Public private modality has to be properly strengthened especially for both distribution and power generation. • By establishing university industry linkage as a priority as well as to design programs to ensure higher education and TVET institutions provide the required manpower. • By advocating/encouraging donor-funded projects (WB, Danida, AFD, etc.) to include technical assistance and technology transfer as a component.	• Continuous capacity building is needed in the following streams- strategy development, energy planning & modeling, creating or developing a greenfield project, project implementation, monitoring and evaluations, impact assessment and new or emerging market and technology utilization; so as to achieve national as well as international commitments in energy or power sector. • As a short-term solution, giving training on different area, work with foreign institutions to get additional support on power sector and for long-term, upgrading through education by scholarship in local universities and foreign universities. • Cooperating with institutions, having capacity development policies and strategies in place. • Investing in professional education and providing employees with training is critical for employees to improve their skills and knowledge, as well as their job performance and possibilities for progress and growth. This increases staff motivation, engagement, competency, and productivity, enable EEP to be competitive and fulfil its goals and vision. EEP has crafted programs to re-establish its training center- so as to create a platform that addresses the capacity limitation of employees. Currently, EEP has reached to deliver training per-annum of 15 man-hours. Various capacity building modalities have been crafted. Among others, certifying employees with an international certification program is to be mentioned. Efforts have also been exerted to create postgraduate programs in electrical engineering, power economics and project management.
Ability of universities to provide relevant knowledge, research, innovation and relevant links to the industry.	• They are good and it's believed that they can deliver on those themes if the contents are well incorporated in their curricula. • Not to the required level but can be improved by increasing the role of local stakeholders and cooperation with foreign universities.	• It is critical. Universities can play a meaningful role in addressing issues of the power sector, especially on renewable energy. • Definitely universities can do so, but strong sector and universities linkages has to be there. • There needs to be a reform or improvement in industry to university linkage in power or energy sectors.

2.6.2. Mapping Energy Capacity across AAiT, ASTU and EiT-M

Table 13 Capabilities, barriers and action options in AAiT, ASTU and EiT-M

Questions	AAiT	ASTU	EiT-M
Field of expertise relevancy level • Energy Planning and Modelling • Transmission and distribution system • Wind energy development • Cross-border electricity trade • Others?	• Highly relevant • Highly relevant • Highly relevant • Somewhat relevant • Solar energy, geothermal energy, nuclear energy, energy efficiency	• Highly relevant • Highly relevant • Highly relevant • Somewhat relevant • Distributed renewable generation, Microgrid, energy management system	• Highly relevant • Highly relevant • Highly relevant • Highly relevant • Hydropower, energy management & conservation, energy efficiency, thermal energy conversion
Extent of education curriculums matching the energy development.	• Existing curriculums partially match the Ethiopian energy industry development. The curriculums require tailoring and aligning with relevant sectorial institutions' plans/needs.	• Existing curriculums partially match the Ethiopian energy industry development. Thers is lack of emphasis on energy related program outcomes.	• Existing education curriculums have been developed based on Ethiopia's energy development need, however, considering the dynamics and fast changing energy landscape, the curriculums need to be constantly revised to match the current and future requirements.
Relevant areas of expertise not provided due to limitations.	• Energy Modelling • Advanced level. courses/trainings on the selected themes with deeper knowledge.	• Energy planning and modelling. • Cross border electricity trade. • Distributed renewable generation. • Microgrid.	• Energy planning and modelling • Cross-border electricity trade • Energy efficiency • Thermal energy conversion • Environmental modelling • Hydrogen energy • Internet of Things (IoT) in energy and digitalization and data analytics • Smart grid technology • Policy economics • Regulation of energy • Environmental Impact Assessment
Staff training, matching industry needs and expanding into new relevant areas of knowledge and research.	• Engaging in multi-national thematic research projects which include capacity-building as part of their objective. • Engaging with oversee universities to establish PG training programmes including staff exchange (e.g.	• Almost non-existing • The existing curriculum is very weak in terms of linkage with industry. • Most trainings are only used for personal career development.	• Leveraging national and international financial support to open new postgraduate programs to train staff. • Networking with international institutions to provide 1) staff an opportunity for exposure visit & laboratory experiment

	SIDA PhD Sandwich program with KTH & Chalmers university in Sweden) • By constantly looking for international opportunities (e.g. PG programs, short-term trainings with state-of-the-art R&D). • Strengthening the industry-university linkage. Currently, the industry-university linkage is rather weak, primarily due to lack of understanding of its purpose on both sides, especially within the industry. Raising awareness is a crucial first step in strengthening this connection.		in addition to their regular study in EiT-M 2) Finding full scholarships to study abroad • Promoting interdisciplinary research projects (e.g. CoE-in-RE-WiSE funded by KfW Germany, UNET funded by Erasmus+, ENET funded by NORHEDD II, CESET funded by GCRF, UK) and partnerships with industry • Providing opportunities for staff to engage with industries to understand industry needs by exposing them to the real-world working environment.
Existing barriers, capacity gaps or challenges in relation to advancing the themes and improving competencies of staff.	• Lack of funding to acquire latest energy/power system software/tools. • Lack of national research funds. • Lack of strong connection with the utility companies for internships, research projects, guest lectures hindering practical learning. • Brain drain-talented graduates are lured to work abroad or in other sectors with higher salaries. • Lack of staff who have specialized on energy/power system. • Insufficient laboratory and R&D facilities.	• Lack of awareness by the university management. • Lack of skilled academic staff. • Financial limitations. • Lack of capacity-building programs & training. • Not directly working with industries concerned with energy related issues. • Low government attention towards advancing the energy sector. • Lack of advanced energy related laboratories and research centers.	• Most staff are young, lacking industry experience. This has a huge impact in producing skilled workforce. • Inadequate financial resources for advanced research and training programs. • Lack of state-of-the-art laboratories and equipment. • Limited number of faculty members with specialized knowledge in emerging energy technologies. • Insufficient partnerships with the energy industry for practical training and internships. • Slow adaptation of curricula to incorporate the latest advancements and industry requirements. • Inadequate government support and policies promoting energy sector education and research.
Existing barriers, capacity gaps or challenges in relation to advancing the themes and improving competencies of students.	• Lack of funding to acquire latest energy/power system software/tools. • Aligning curriculum with the rapidly evolving power sector and incorporating new technologies is challenging.	• Lack of research laboratories in the energy area. • Curriculum gap. • Lack of student involvement in energy projects.	• Though the university is trying its best to link students to the power sector through internship programmes and site visits, it has never been sufficient which in turn affects the necessary competencies and skills that the students are expected

	• Lack of strong connection with the utility companies for internships, research projects, guest lectures hindering practical learning. • Incoming students lack strong foundation in science, technology, engineering, and mathematics (STEM) subjects, making it difficult for them to grasp advanced energy sector concepts. • Matching industry needs: Ensuring graduates have the specific skillsets employers in the power sector are looking for can be difficult. • Focus on traditional methods: Curriculums might overemphasize hydropower at the expense of newer renewable energy sources. • Brain drain: Talented graduates are lured to work abroad or in other sectors with higher salaries. • Students declined interest to study energy/power engineering due to less pay by employers.		to acquire as part of their studies. • Lack of laboratories related to the energy sector. • Inadequate financial resources for advanced research and training programs. • Limited number of faculty members with specialized knowledge in emerging energy technologies. • Insufficient partnerships with the energy industry for practical training and internships. • Slow adaptation of curricula to incorporate the latest advancements and industry. • Inadequate government support and policies promoting energy sector education and research.
Opportunities and/or pitfalls in collaboration with local stakeholders and foreign universities.	**Opportunities:** • Enhanced Curriculum & Training: Collaboration can help update and enhance the curriculum to meet international standards, ensuring graduates are well-equipped with the latest knowledge and skills. It also allows universities to leverage the expertise of affiliated institutions (MoWE, EEP, EEU, PEA) and foreign universities. This can lead to a curriculum that is more relevant to current industry needs, incorporates the latest technologies, and offers practical training opportunities like internships and guest lectures from industry professionals.	• There are huge opportunities in collaborating with local affiliated institutions and foreign universities.	• EiT-M is making every effort to forge a strategic partnership with local and international institutions, but they are never sufficient. More work needs to be done to strengthen the working relationships, particularly with the local power sector to collaborate and solve the key challenges of the energy sector. Their weak working relationship between the academic sector and the energy sector in Ethiopia, needs to be fixed if we want to advance the energy sector in the country. Both institutions should be open and trust each other and believe on the mutual benefits of

	• Resource sharing: Partnering with established institutions can provide access to advanced laboratories, research facilities, and educational resources that may not be available locally. • Faculty Development: Joint programs and exchanges can facilitate faculty development, improving both teaching and research. • Research and innovation: collaborations can spur joint research projects, fostering innovation and providing solutions tailored to local challenges in the energy sector. • Funding and Grants: collaborative efforts may attract funding from international donors and grants unavailable or otherwise inaccessible to institutions working independently. • Increased Student Employability: Strong industry connections gained through collaboration with power utilities can open doors for internship and job opportunities for graduates, making them more competitive in the workforce. **Pitfalls:** • Coordination challenges: Effective collaboration requires substantial coordination and communication, which can be difficult to manage across different institutions with varying priorities and administrative structures. • Equity and inclusion: If the collaboration is not structured effectively, universities might not benefit equally from the expertise and resources of foreign partners. Ensuring that benefits are equitably distributed among all partners, including		working together, which will be helpful to advance the sector to a higher level but working in a silo will not solve our challenges in the sector. • Opportunities regarding university power industry linkage include: 1) resource sharing for access to advanced facilities and funding, 2) expertise exchange for learning from experienced professionals and researchers 3) enhanced curriculum for updating and diversifying educational programs, 4) joint research for collaborating on innovative energy projects and solutions, 5) internships and training for providing practical experience through industry placements. • The Pitfalls includes: 1) coordination challenges 2) sustainability for ensuring long-term commitment and benefits from the collaboration, and 4) resource dependency.

	smaller local institutions, is crucial to avoid imbalances that could undermine the partnership. • Dependence on External Partners: Over-reliance on foreign institutions for resources and expertise might limit local capacity building and self-reliance. • Intellectual Property Issues: Sharing research findings and knowledge needs to be carefully navigated to ensure proper credit and ownership of intellectual property. • Cultural and administrative differences: Differences in academic and organizational cultures can complicate aligning goals, expectations, and working methods. • Sustainability: Ensuring project sustainability beyond initial funding periods can be challenging, requiring long-term commitment from all parties involved.		
Success and any encountered challenges with your industry-tailored programs.	• Successfully trained and graduated one-batch (i.e. 25 staff of EEPCo) that are now serving at various managerial and expert positions of EEP. That did not continue due to unsustainability of funding.	• N/A	• The thermal and energy systems chair has an industry tailored programme with Mesfin Industrial Engineering. The industry is training its employees in this programme. The programme is called MSc in thermo-fluids engineering. The programme has been running smoothly for years but ceased operation during the last three years due to the war. The programme will soon be revived and will continue providing training for the industry employees.
Future plans that may positively impact the energy sector.	• With the completion of staff that are PhD students, the School of Electrical and Computer Engineering plans to work closely with relevant stakeholders to implement some of	• There is huge interest in starting energy related programs and provide trainings that bridges industry gaps. • Establish an Energy center in the already	• The chairs that are responsible to provide energy related courses are putting a lot of effort to increase the number of staffs at PhD level so that they can conduct different

	their dissertation ideas that can benefit the Ethiopian energy sector. • The Center of Renewable Energy in AAiT plans to start a PhD program and also provide industry need-based capacity building programs/trainings.	established Research Park.	researches to solve the key problems of the energy sector in Ethiopia. • Expand and strengthen networking with national and international institutions. • Establish a Center of Excellence in Renewable Energy that focuses on research, innovation, and training in renewable energy technologies.
Primary considerations when initiating twinning between Danish and Ethiopian universities.	• While collaboration with Danish universities presents a significant opportunity to strengthen Ethiopian universities and better prepare graduates for the power sector, it is essential to address potential pitfalls through careful planning, clear agreements and ongoing dialogue. • Joint researches, joint ownership of high-end research centers/center of excellence in renewable energy, fine-tuning curriculums, student & staff exchanges on prioritized specialty areas.	• Faculty training and research center establishment.	• Capacity building of university staff through 1) facilitating exposure visits & laboratory works for home-based PhD students, 2) add oversee supervision to alleviate the lack of local supervisors, 3) opening fully funded PhD opportunities tailored to the need of the local universities. • Joint research programmes to solve key energy-related challenges within each country and on the globe. A consortium can be formed with common research interests and application can be made together to any Danish or other funding opportunities. • Alignment of expertise, mutual goals and objectives, sustainability, equitable partnership, flexibility and adaptability.

2.7. GIS Mapping of the energy programs and capabilities

GIS mapping of the energy education programs in the three universities gives a visual understanding of the location where energy programs are being taught and it has been done on Public Tableau software as depicted in Figure 6 and in the following web-link Link_to_the_GIS_Mapping. The map can be uploaded on relevant project websites.

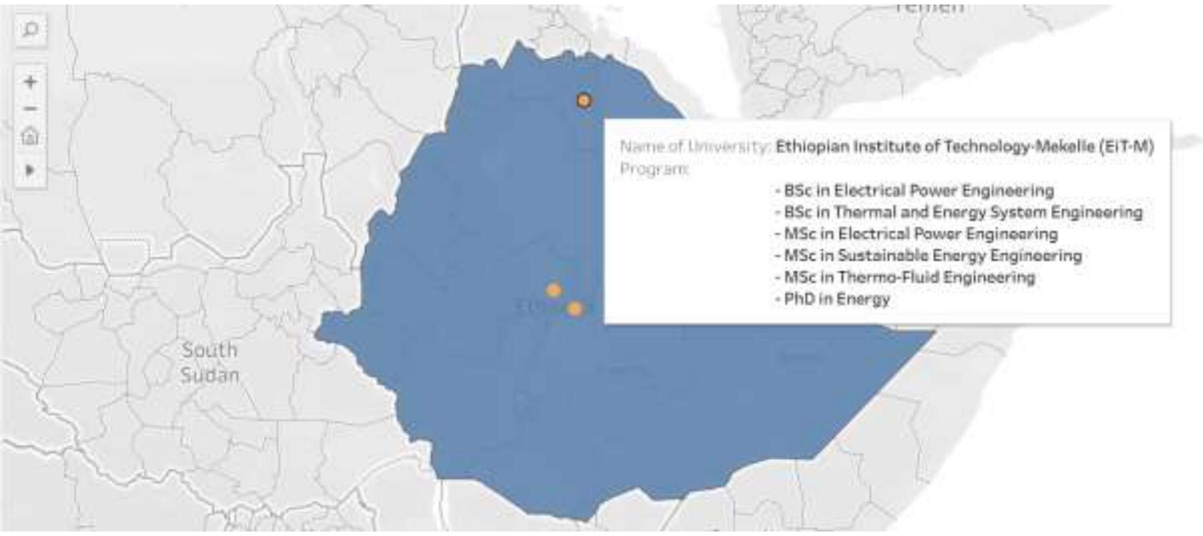

Figure 6 Mapping of energy education programs in the three universities

3. Result and Discussion

In this mapping study, three public universities are assessed if they are teaching energy programs and/or energy-related courses (i.e. existing educational curriculums) and their teaching & research capabilities. In addition, representatives of relevant utility stakeholders have been engaged to understand on how and to what extent themes and areas of expertise match the needs and requirements of the Ethiopian energy sector.

Based on the investigation of the curriculums, it is found that all the three universities run Electrical Power Engineering program in both UG and PG levels. In terms of number and variety of programs, EiT-M runs more energy programs than AAiT and ASTU. AAiT and EiT-M give other energy programs (i.e. AAiT: Renewable Energy Technology; EiT-M: Thermal and Energy System Engineering, Sustainable Energy Engineering & Thermo-Fluid Engineering) while ASTU only offers Electrical Power Engineering program at undergraduate and postgraduate levels. In terms of human capacity, EiT-M also has a greater number of academic staff who have specialized in the field of energy. With regard to research capability, the survey has shown that AAiT and EiT-M have established several collaborations worldwide and they have been engaged in many research projects. It is also to be noted that all levels of education have been interrupted while EiT-M and other universities across Tigray were closed due to the two-year-old war.

The investigation also revealed that energy as a full-fledged program is not given at BSc level in any of the three universities despite having the Electrical Power Engineering program. Instead, selected energy courses are included in the undergraduate program mainly during specialization (4th and 5th-year) in Electrical Power Engineering. In this regard, more energy courses need to be integrated into the UG curriculums. Furthermore, fundamental renewable energy courses could be introduced for first-year or second-year engineering students as a common course so that they get used to the concept of renewable energy at the very early stage of their undergraduate studies. Introducing renewable energy courses to the undergraduate curriculum would not only make students environmentally aware and develop a sense of responsibility for their actions on the environment but would also set the foundation of interest and pathway through which students may get involved with renewable energy projects and become innovative with their ideas.

Unlike the BSc level, standalone energy education is being given at MSc and PhD levels in all the three universities. The energy courses vary across the three universities and type of programs. However, it can be noted that specific courses (e.g. energy system modelling and planning, variation management in the electricity system) that are regarded as highly relevant by the three universities in driving the sustainable economic development and support the development of renewable energy are not mostly present in the curriculums.

The survey responses highlighted the fact that there is lack of adequate laboratory for renewable energy teaching and research. Renewable energy education should be accompanied by practical methods of teaching (such as laboratory experiments) to promote students' engagements and increase effectiveness.

4. Conclusion and Recommendations

Energy education and training pave the way for meeting the Sustainable Development Goals (SDGs) and national targets by producing energy-aware graduates. Energy learning helps engineers and technicians to grasp profound knowledge and hands-on skill in renewable technologies. In this regard, academic institutions are seen as being at the center of capacity-building initiatives for the energy sector. However, the success of the energy transition, will depend to a large extent on the concerted and collaborative effort of all key stakeholders and actors (policymakers, regulators, utilities, practitioners, etc.). Unfortunately, the university-industry linkage and collaboration specifically on capacity-building has been weak in the energy sector of Ethiopia. There were frequent discussions and consultations over the years but not something tangible and sustainable has been achieved so far. Furthermore, inadequate government support to enhance energy education and research, aligning curriculum with the rapidly evolving technologies, limited knowledge within the theme areas including energy planning and modelling and lack of appropriate research facilities are identified as major limiting factors. In light of this, collaboration with local affiliated institutions (MoWE, EEP, EEU, EPEA) and foreign universities is essential.

This study has marked that the supply of highly skilled workforce in the energy/ power sector of Ethiopia is limited. Thus, special trainings are necessary for personnel at every level in the industry to keep abreast with rapidly advancing state of the-art in the energy/power industry. Unless and otherwise the utilities have a pool of committed and competent professionals equipped with appropriate technical skills to steer the sector, the country's energy sector will remain noncompetitive and inefficient that hinders innovative advancements across sectors of the economy and reduces Ethiopia's competitiveness in the global market.

Based on the findings of this study, several recommendations are proposed as discussed below.

Government intervention – adequate funding for renewable energy research: Government should provide generous funding for renewable energy research in public universities, and also invest in the building and construction of state-of-the-art laboratories for renewable energy research and development.

Resource sharing – among universities & industry: Facilitating shared use of existing laboratory resources among the three universities and utilities - EEP, EEU, EPEA (if any) could be essential in enhancing the research and teaching-learning by engaging students in demonstrative experiments and hands-practicals on renewable energy. Universities could also strengthen their partnership with energy industries to train students (e.g. internships) and empower them with the technical skills needed to thrive in the energy sector.

University-industry collaboration: Some suggestions to strengthen the university-industry collaboration include 1) establishing formal platforms for communication: forums, conferences and exhibitions with active participation from both academia and industry. Professional associations and the Danish Embassy in Ethiopia have a unique position in making these connections happen as they both work closely with both academia and industry, 2) Clarity on specific deliverables: Beyond outlining the mutual goals and general terms of understanding in MoUs, agreements should include specific pathways, budget, deliverables and timelines that partners intend to work on. 3) Forge long-term collaborations through creation of an advisory board with industry representatives that provide real-time input on curricular and research activities.

Collaboration with foreign universities and partners: Local industries may not be ready or robust enough to provide the required support for research in higher education institutions in Ethiopia. Therefore, universities must widen their horizons by looking global. Following the SIDA funded Ethio-Sweden PhD program being implemented in AAiT, access to finance and advanced energy laboratories for postgraduate research could be facilitated with Danish universities through mutual-student and staff exchanges.

Industry tailored programs: As pointed-out in the survey, the courses offered in the regular university curricula usually lack the practical insight and as a result the graduates lack the practical skill to solve the technical and operational problems of the industry. It is therefore necessary to further enhance the human resource capacity of the industry through a major capacity building process. The best way of doing this is to establish an industry-tailored training program (e.g. MSc) in the university. The program should train the industry's staff who will be equipped with the necessary skills and knowledge to address the specific needs and challenges of the particular industry. Industry-oriented programs and short-term trainings are also very essential to cope-up with the advancements in the energy/power sector and improve the competencies of the workforce in the industry. In this regard, it would be important to recontinue and expand the industry-tailored energy programs that have been running in AAiT and EiT-M. Also considering ASTU's endeavors of becoming a center of excellence in science and technology, the university could also follow the same suit to strengthen its industry linkage and contribute to the uplifting of workforce's capabilities.

International certification training programs: Allowing students, faculties and utility employees the opportunity to gain on-the-job-learning that supplements knowledge gained in their formal academic studies through various specialized courses (e.g. DFC learning programmes). Universities and employer organizations can integrate and recognize such training programs through transfer of course credits and certifying employees, respectively.

Reduce the gender gap in energy sector: In order to make energy and engineering a more welcoming and attractive choice for women, organizations need to ensure they have an organizational culture that supports and retains them starting from early education to higher education and workplaces by encouraging and empowering women to enter the STEM workforce.

Open-Source Energy Modelling Tools: Introducing free, open-source energy modelling and simulation tools to be used in the academia for delivering courses and doing research to better understand the energy system and provide insights into investment and infrastructure needs, operational aspects, assessing the transition to renewables, etc.

Appendix A: Bibliography

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Appendix B: Data Collection: Survey Questionnaire

I. Questions for utility stakeholders

Welcome to the Energy Planning Survey!

(To be filled by Ministry of Water and Energy (MoWE), Ethiopian Electric Power (EEP), Ethiopian Electric Utility (EEU), Petroleum and Energy Authority (PEA), Ministry of Finance (MoF), Ministry of Planning and Development (MoPD))

This Google Form has been prepared to get your views on how and to what extent themes (i.e. general areas of activities) and areas of expertise in your organization match the requirements of the energy sector in Ethiopia. Your input will be invaluable to understand the achievements, existing barriers, human capital and capacity gaps in the Ethiopian power sector that will in turn be useful to design effective interventions and mitigation strategies.

Please take a few moments to complete the form by responding and sharing your thoughts on all the items.

Thank you in advance for your participation and valuable input.

Please provide your name, position and the organization or institute you are affiliated with:

……

What are the main priority areas or themes of the energy/power sector in Ethiopia?

……

Which of the following themes do you consider to be relevant for the development of the energy sector in Ethiopia?

1. Energy Planning and Modelling
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
2. Transmission and distribution system
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
3. Wind energy development
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
4. Cross-border electricity trade
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant

5. Other themes you consider relevant

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………………………………………………………………………………

How do you assess the extent to which the current level of skills and knowledge in your organization match the demand for such skills i.e. what is required for energy development in Ethiopia?

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………………………………………………………………………………

Mention some of your organization's achievements in terms of advancing the identified themes.

Please give an example of your organization's achievements in terms of advancing:

1. Energy Planning and Modelling
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………………………………………………………………………………
2. Transmission and distribution system
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………………………………………………………………………………
3. Wind energy development
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………………………………………………………………………………
4. Cross-border electricity trade
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5. Achievements in other relevant themes
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………………………………………………………………………………

Mention the existing barriers or challenges your organization is facing in the Ethiopian power sector specifically in relation to advancing the themes?

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With Ethiopia's present activities and planned ambition to expand its power sector, added with system complexity and advancement in technology, the demand for future experts is expected to be high. Aiming to secure these future experts and create a sustainable change, how do you work with further education, training or competence development strategies to meet the demand of the energy sector in Ethiopia?

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How do you perceive the ability of universities to provide relevant knowledge, research, innovation and relevant links to the industry?

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Thank you for filling this questionnaire. Any further comments?
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II. Questions for universities

Welcome to the Mapping University Curriculums with Energy Planning Survey!

(To be filled by Addis Ababa Institute of Technology (AAiT), Adama Science and Technology University (ASTU), Ethiopian Institute of Technology-Mekelle (EiT-M))

This Google Form has been prepared to learn about the existing education programs, energy courses, research capabilities (projects, researchers, publications), international collaborations, capacity gaps and other activities undergoing in your university. Your input will be invaluable to understand your university's achievements, existing barriers, human capital and capacity gaps that will in turn be useful to design the appropriate curriculum and twinning project with the Danish universities.

Please take a few moments to complete the form by responding and sharing your thoughts on all the items.

Thank you in advance for your participation and valuable input.

Please provide your name, position and the university you are affiliated with:

………

Please indicate how relevant you consider the following fields of expertise:

1. Energy Planning and Modelling
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
2. Transmission and distribution system
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
3. Wind energy development
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
4. Cross-border electricity trade
    a. Highly relevant
    b. Somewhat relevant
    c. Not relevant
5. Other relevant fields of expertise

………
………………………………………………………………………………

How do you perceive the extent to which the existing education curriculums match the requirements of energy development in Ethiopia?

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Which areas of expertise do you not currently provide even though you perceive them as being relevant for the energy industry?

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How do you currently work with training of staff, matching industry needs and expanding into new relevant areas of knowledge and research?

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Mention the existing barriers, capacity gaps or challenges your university is facing in the Ethiopian power sector specifically in relation to advancing the themes and improving competencies of staff?

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Mention the existing barriers, capacity gaps or challenges your university is facing in the Ethiopian power sector specifically in relation to advancing the themes and improving competencies of students?

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Universities have a crucial role of producing graduates who are equipped with the necessary skills and knowledge capable and confident to address the needs of the electric power sector in the country. However, the Ethiopian universities are not in a position to face this challenge alone. Collaboration with local affiliated institutions (MoWE, EEP, EEU, PEA, MoF, MoPD) and foreign universities could be a way forward. Which opportunities and/or pitfalls do you see in such a collaboration?

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What are the existing undergraduate and graduate education programs related to energy in your university? Please also state the total number of students enrolled in the respective programs.
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Please list the existing courses in the respective energy programs (you can also send curriculum/s which is highly appreciated).

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Which university unit (School, Department, Center, Chair, etc.) teaches the energy education?

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When did the university start teaching energy? How often does the curriculum get revised?
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Please list any (energy) industry-tailored programs your university has been/is running to bridge the skill-gap and produce competent workforce in the energy industry. Also please briefly comment on its success and encountered challenges (if any).

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Please list any local energy projects your university has been/is working in partnership with national institutions (if any).

………

Please list any international energy projects/research collaborations your university has been/is working on in partnership with foreign universities/institutions.

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Please list any existing collaborations between your university and local organizations/industries in the energy/power sector.

………

Please list any existing energy related collaborations between your university and foreign universities/institutions.

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Please mention the number of permanent academic staff or researchers in your university with their focus area in the energy field.

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Do you rely on part-time or visiting Professors for teaching special/elective/advanced energy/power courses? Please mention the courses here.

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Mention any future plans or directions your university has set forth that could positively impact the energy sector of Ethiopia.

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The Enhanced Denmark Ethiopia Energy Partnership (DEEP) has a university component that aims at engaging Ethiopian and Danish universities to further enhance the transfer of knowledge between the national institutions including three Ethiopian universities and three to four universities from Denmark. What should be, according to you, primarily considered when initiating the twinning between Danish and Ethiopian universities?

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Thank you for filling this questionnaire. Any further comments?

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Appendix C: List of organizations included in the survey

I. Utility Stakeholders

Ministry of Water and Energy (MoWE)

Petroleum and Energy Authority (PEA)

Ethiopian Electric Power (EEP)

Ethiopian Electric Utility (EEU)

Ministry of Finance (MoF)

Ministry of Planning and Development (MoPD)

II. Universities

Addis Ababa Institute of Technology (AAiT), Addis Ababa University (AAU)

Adama Science and Technology University (ASTU)

Ethiopian Institute of Technology-Mekelle (EiT-M), Mekelle University

Appendix D: Description of some selected courses in AAiT, ASTU & EiT-M

i. Addis Ababa Institute of Technology (AAiT)
• **MSc Program of Electrical Power Engineering**
Module Name: Power System Modelling
Course Name: Power System Planning & Management
Course Objectives: To provide detail understanding of load forecasting techniques, to provide a sound understanding of calculation of transmission losses, economic load dispatch and optimal operation of power systems, to provide understanding of cost analysis of generation systems. **Course Content**: Basic objectives of power system planning. electrical demand forecasting, current demand forecasting approaches, economic analysis: expected energy generation, expected fuel cost, Booth-Baleriaux' Method or Load Duration Curve Method, Cummulant and Segmentation methods, expected energy production cost of interconnected systems, economic aspects of interconnection, probabilistic simulation of hydro and energy limited units, generation planning: single-bus and multi-bus generation expansion planning process, network expansion planning: different aspects of load management, effects of load management on reliability and production cost, joint ownership of generation. **Teaching and Learning Methods**: Lectures, Self-study, Seminar presentation, project, case study, experimentation, industry visit, research.
Module Name: Renewable Energy and Energy Saving
Course Name: Distributed Generation and Renewable Energy Technologies
Course Objectives: To provide students with an understanding of the significance of renewable and distributed power generation and their implications on the operation of modern electric power systems. **Course Content**: Overview of thermodynamics, hydropower engineering, mini-hydropower, introduction to solar energy systems, photovoltaic system, solar-thermal engineering, introduction to wind energy, wind power generation, basics of biomass energy, distributed generation; an introduction, combustion engine generation sets, combustion turbines, photovoltaic systems, microturbines, fuel cells, energy storage, economic and financial aspects of distributed generation. **Teaching and Learning Methods**: Lectures, Self-study, Seminar presentation, project, case study, experimentation, industry visit, research.
Module Name: Transmission and Distribution Systems

Course Name: Transmission and Distribution Engineering
Course Objectives: To make the student familiar with the transmission and distribution of electrical energy, to enable students search for analysis and synthesis of data with the use of necessary technology. **Course Content**: Overview of overhead and underground ac transmission systems, transmission line parameters, representations and characteristics of ac transmission lines, capacitance of cable, insulation resistance and dielectric stress of cable, cable sizing, conductor design and kelvin's law representation of 2-winding and 3-winidng transformer connections, power transfer between active sources, HVDC transmission, distribution system: distribution system planning and automation, load characteristics, load forecasting, design of sub-transmission lines and distribution substations, design considerations of primary and secondary systems, application of capacitors to distribution systems, voltage regulation and load management. power system protection: basic principles of protection, elements of protection system, high circuit breakers and relays, selection of circuit breakers, zones of protection, primary and backup protection, reclosing. transmission line protection: typical relays used on transmission lines, over-current relays, distance relays, pilot relaying, computer applications in protective relaying. distribution system protection: objectives of distribution system protection, coordination of protective devices, high-fault impedance, lightning protection. **Teaching and Learning Methods**: Lectures, Self-study, Seminar presentation, project, case study, experimentation, industry visit, research.
• **MSc Program of Renewable Energy Technology**
Module Name: Basic Renewable Energy
Course Name: Wind Energy
Course Objectives: At the end of this course, students would be able to: Understand the basic principles of wind energy conversion, know the different types of wind machines and their performances, estimate the wind energy potential of a site, model wind energy conversion system (WECS), understand environmental and economical aspects of wind energy. **Course Content**: Introduction to Wind Energy: History of wind energy, Current status and future prospects, Wind energy in Ethiopia, Basics of Wind energy conversion, Wind energy conversion systems: Wind electric generators, Wind farms, Wind pumps, Performance of wind energy conversion systems, Wind turbines, Energy generated by the wind turbine, Capacity factor, Matching the wind turbine with wind regime, Performance of wind powered pumping systems, Wind energy supply systems, Wind energy transmission and Storage, Wind system efficiency, Economics of wind energy, Project work on wind energy. **Teaching Strategy/Methods**: Lectures, Exercise, Project work.
Module Name: Conservation of Energy and the Environment, Energy Economics and Energy Systems and Project Management
Course Name: Energy Project Planning and Management
Course Objectives: Following successful completion of the course, students will be able to understand: Comparison between technologies (Hydropower, Solar PV, Solar PV Mini-grid, Wind, etc), Modern project planning, monitoring and evaluation techniques in the context of public sector projects, How to select projects using multiple criteria, Understand the main types of feasibility analysis, Understand the basic concepts of financial and economic cost-benefit in project management. **Course Content**: 1) Comparison between technologies: Comparison between technologies at system level and understanding the economics of different technology options in a specific country context using open-source energy modeling tools. OSeMOSYS can be an option to demonstrate the economic trade-offs between different technology options under a range of scenarios linking the energy sector to policy and regulation. 2) Manage a specific project: Project selection as a multiple-criteria decision problem; Main types of feasibility analysis, basic concepts of financial and economic cost-benefit analysis, measures of project worth; Financial appraisal of projects (profitability and liquidity analysis); sensitivity analysis; Shadow pricing, treatment of project spillover effects etc., Additional topics include Project life cycle, work breakdown structure and Gantt charts, network diagrams, scheduling techniques, and resource allocation decisions and project team selection development and improvement. **Teaching Strategy/Methods**: Lectures, Case studies, Term Papers, Individual and group assignments.
Module Name: Modelling, Optimization and Integration
Course Name: Modelling and Optimization of Renewable Energy System
Course Objectives: To develop computational models for different type of renewable energy systems by which the performance of the system is optimized. **Course Content**: Introduction to Matlab, Introduction to statistical distribution. and application to energy resources, Solution of system of non-linear time dependent ODE by Runge kutta, finite difference method,

Solution of PDE by finite difference method, Optimization techniques: identify objective function, constraints, variables and parameters, optimization algorithms such as linear programming, steepest ascent genetic algorithm and others, Modelling of annual performance of solar, wind and hydropower system, System integration (how different energy technologies work together) with an existing transmission grid; Modelling of on-grid and off-grid technologies (using dispatch modelling for an hourly time-slice, like OSeMOSYS). **Teaching Strategy/Methods**: Lectures, Exercises and Project Work.
• **PhD Program of Electrical Power Engineering**
Course Name: Power System Planning and Management
Course Description: Basic objectives of power system planning, Generation expansion planning process, Electrical demand forecasting; current demand forecasting approaches, Generation planning, economic analysis, expected energy generation, expected fuel cost, Both-Baleriux, cummulant and segmentation methods, Probabilistic simulation of hydro and energy limited units, Expected energy production cost of interconnected systems, Economic aspects of interconnection, Different aspects of load management, effects of load management on reliability and on production cost, Joint ownership of generation.

ii. Addis Ababa Science and Technology University (ASTU)
• **MSc Program of Power Systems Engineering**
Course Name: Optimization Techniques in Power Systems
Course Description: Classical optimization techniques, linear programming, nonlinear programming, geometric programming, dynamic programming, integer programming, stochastic programming, optimal control and optimality criteria methods.
• **PhD Program of Electrical Engineering**
Course Name: Transmission Systems Engineering
Course Description: Modeling of electrical parameters, Selection of voltage level, Insulation design criteria, Design of transmission lines: Terrain modeling, survey data, and plan-profile, Conductor design, modeling, and sag-tension calculations, Structure modeling, Geometry, Strength, and Spans, Interactive line design and optimization, Development of HVDC technology: Principles of HVDC conversion, AC & DC harmonics and filtering, Economics comparison with HVAC systems, General arrangement and layout of switchyard, Switch gear, Power transformers.

iii. Ethiopian Institute of Technology (EiT-M)
• **MSc Program of Electrical Power Engineering**
Module Name: Applied Electrical Power Engineering
Course Name: Renewable Power Generation Technology
Course Description: The course covers solar and wind energy system, hydroelectric power generation, hybrid energy system, distributed generation and micro-grid system. **Course Objectives**: Upon successful completion of this course the students will be able to: Learn the characteristics of renewable energy and the environment, analyze trends and requirements of renewable energy sources, analyze capacities and limitations of RETs, design PV, wind energy, hydro and hybrid systems, use simulation software for the analysis of renewable generation system, apply RETs to rural electrification and conduct studies related RET policies, design a micro-grid system, taking into consideration the planning and operational issues of the distributed generation system to be connected into the electrical network. **Course Content**: Solar and wind energy system, Hydroelectric power generation, Hybrid energy system, Distributed generation and micro-grid system. **Teaching Method**: Lectures, Tutorials, Project work, Term Papers, Presentations, Assignments and Laboratory Activities.
Module Name: Advanced Power Systems Engineering
Course Name: Power System Planning and Management
Course Description: The course covers Load forecasting, generation and transmission systems reliability analysis, expansion and distribution system planning, energy management for electrical machines and lighting systems. **Course Objectives**: Upon successful completion of this course the students will be able to: Forecast load and study expansion and distribution system planning, learn reliability analysis of generation and transmission

systems, apply probabilistic and deterministic solution methods to reliability, analysis and determine reliability indexes, to understand and comprehend load management and its effects on production cost and reliability of interconnected power systems, understanding of concepts and techniques of power system planning and generation expansion planning, gather and analyze power system data for energy auditing, learn mathematical equations, re-engineering and equipment upgradation for existing systems and value environmental sustainability and economic return of existing power system facilities, to carry out production cost analysis of expected energy generation, for interconnected systems and probabilistic simulation studies of hydro and energy limited generation units. **Course Content**: Load forecasting, Generation and transmission systems reliability analysis, Expansion and distribution system planning, Energy management for electrical machines and lighting systems. **Teaching Strategy/Methods**: Lectures, Tutorials, Project work, Term Papers, Presentations, Assignments and Laboratory Exercises.
• **MSc Program of Sustainable Energy Engineering**
Course Name: Energy Conservation and Management
Course Objectives: To develop a fundamental understanding of the basic physical principles underlying energy management and audit, energy efficiency in thermal and electrical utilities, energy storage systems and power cogeneration, aims at providing skills required to identify and implement energy conservation, overview of the effects of power generation and energy utilization on ecology and climate. **Course Content**: Energy Conservation, Energy Management, Energy Audit, Material and Energy Balance, Energy Monitoring and Targeting, Global Environmental Concerns. **Teaching Strategy/Methods**: Lectures, exercises, Laboratory work, Assignment, study visits
Course Name: Wind Energy
Course Objectives: To understand the basic principles of wind energy conversion, to provide the student with knowledge of the various aspects of the production and consumption of wind energy, estimate the wind energy potential of a site, model wind energy conversion system, understand environmental and economic aspects of wind energy. **Course Content**: History of the usage of wind as an energy resource, Wind turbine geometry, Design Loads for Wind Turbines, Wind-turbine installation and wind farms. **Teaching Strategy/Methods**: Lectures, exercises, Laboratory work, Assignment, study visits
Course name: Modelling and Simulation in Energy Technology
Course Objectives: Designing/analyzing energy technology and environmental systems, Provide the skill and competence with regard to modeling and simulation in energy technology. **Course Content**: General aspects of modeling methodology, Classification modeling and simulation, different types of modeling, introduction to modeling, Statistical models. **Teaching Strategy/Methods**: Include formal lectures (Including visiting lecturers), case studies, tutorial exercises, practical demonstrations, directed learning and individual work.
• **PhD Program of Energy**
Course Name: Wind Turbine Design
Course Description: The characteristics of the wind, Meteorology, Earth boundary layer, Wind data, Wind data analysis, Extreme wind velocities, Wind measurements & instrumentation, IEC standards on wind measurements, Wind turbine types and classification, Horizontal and vertical turbine types, Wind turbine power measurements, Main aerodynamic calculations for wind turbines, Wind turbine components, gear and gearless systems; Generators; Power electronics used; Blades; Materials and manufacture; Control equipment; Switch gears, Grid connection, Topography basics used in the wind energy planning, Wind turbine and wind park energy analysis, IEC standards for turbine classification, Wakes, Turbulence analysis, Offshore wind energy, Wind energy integration in the decentralized power grid; Storage systems, and Hybridization of wind energy systems. **Teaching learning Methods:** Lectures and Tutorials, Labs, Seminars, Compulsory assignments, Specific conditions, Exercises.