TRAINING REPORT

INTRODUCTION TO GEOTHERMAL SCIENCE AND TECHNOLOGY
FOR THE ETHIOPIAN ENERGY AGENCY

Under the Auspices of The Interim Project Coordination Unit –
Africa Geothermal Centre Of Excellence (IPCU-AGCE)

TRAINING DATES & VENUE:

12th -21st August 2019 Part I: Geothermal Resources Exploration,
GDC Polo Centre, Nakuru, Kenya
21st August -2nd September 2019 Part II: Geothermal Resources Utilization, Energy Status and Regulation
KenGen Olkaria Complex, Naivasha
"Excellence is an art won by training and orientation"
African countries reached to a consensus of establishment and operation of the Africa Geothermal Center of Excellence in the context of (a) Regional Relevance: Align the Center with the regional needs and requirements; (b) Regional Ownership: The Center will be owned and led by all Africans and have all African Players on board; (c) Build on Existing Initiatives: Utilize the existing facilities and initiatives. The Government of Kenya hosts the Center due to its existing and advanced institutional and infrastructural capacities including where the geothermal development value chain can be easily showcased and exhibited.

Africa Geothermal Center of Excellence aims to create a critical mass of experts in geothermal science and technology to address the challenges of inadequate local skilled manpower in the geothermal sector and enhance access to clean energy and green jobs in the region. This is being implemented in the context of providing innovative environmental solutions to achieve the various Global Sustainable Development Goals and Continental AU development Agenda of 2063: SDG 7, SDG 5, SDG 17 etc.

The Africa Geothermal center of Excellence Steering Committee members held a series of meetings since August 2015 where it made a decision to set up an Interim Project coordination unit of AGCE (hosted by UN Environment Africa office) in order to meet the urgent training need and requirements of African countries while the full-fledged AGCE is established. UN Environment was tasked to provide technical support and develop an interim strategy, with stakeholders including holding a series of geothermal trainings using the existing Geothermal Development Company (GDC) and Kenyan Electricity Generating Company (KenGen) training facilities under the auspices of IPCU AGCE.

The second AGCE stakeholders workshop held in Djibouti, September 2017 Launched the IPCU-AGCE and endorsed the various geothermal training modules that will be conducted under the auspices of IPCU-AGCE. In a similar vein, IPCU-AGCE had conducted a training needs assessment from participating countries upon which a training plan was developed for the interim phase of the AGCE. This assessment provided information on (i) 5-year strategic plan for geothermal exploration and development (power generation and direct use application); and (ii) the needs for training in each geoscientific, drilling and engineering fields in the coming 5 years.

In line with this, UN Environment Africa office and the United States Energy Association (USEA) joined forces and organized a training on the “Introduction to Geothermal Science and Technology” for The Ethiopian Energy Agency trainees. The training was conducted under the auspices of the Interim Project Coordination Unit – Africa Geothermal Centre of Excellence (IPCU-AGCE) and held from 12 August to 2 September 2019. It was divided into two parts. Part 1 was on Geothermal Resource Exploration and was conducted from 12th -21st August 2019 at the GDC Polo Centre, Nakuru, Kenya. Part 2 was on Geothermal Resources Utilization, Energy Status and Regulation and held on 21st August -2nd September at the KenGen Olkaria Complex, Naivasha. The training was intended to build capacity for trainees from the Ethiopian Energy Agency (EEA) in basic geothermal resources development. This training was conducted under the auspices of the IPCU-AGCE. IPCU-AGCE is technically and financially supported by UN Environment and the Ministry for Foreign Affairs Icelandic International Development Agency (MFA-ICEIDA)

Below kindly find the compiled report for the training.
The Geothermal Science and Technology Training kicked off on a good note at Nakuru Geothermal Development Company (GDC) Office for trainees from the Ethiopian Energy Agency (EEA). The opening ceremony was held at the GDC Polo Centre Boardroom. The ceremony was graced by the EEA trainees, IPCU - AGCE, representatives from USEA, KenGen and GDC Management. GDC MD & CEO Representative and Ag. Regional Manager Central Rift, Mr. Gabriel Wetang’ula opened the training by giving the opening and welcoming remarks. This was after introductions of the trainees, trainers and other stakeholders was done. Other welcoming remarks were done by Mr. Peter Ndirangu representing the KenGen CEO, where he reiterated on the sound collaboration between the two facilitating agencies for a common objective of building geothermal capacity for the region. Ms. Ashley Ndir from the United States Energy Association (USEA) as the sponsorship agency also gave opening remarks stating on behalf of USEA how pleased she was on seeing the training officially kick off and for the warm welcome she received in GDC and Nakuru.

The UN Environment Africa Office, Project Manager Ms. Meseret Zemedkun then gave a presentation on the current status AGCE that is from Concept to Implementation. She briefed on the rational for establishment of African-Based Geothermal Center of Excellence, the background, IPCU-AGCE , the trainings conducted so far, E-learning and the way forward.

The training started with an opening lecture on the objective of the Geothermal Science and Technology training under the auspices of the IPCU-AGCE and introductory lectures covering the following: (i) Geothermal Systems in Global Perspective: Definition, occurrence of various types of geothermal resources with emphasis on East African Rift System and others parts of Africa; (ii) Overview of geothermal exploration methodology and approach; (iii) Types and Classification of Rocks (Igneous/Sedimentary/Metamorphic) with emphasis on Igneous petrology/Volcanology; (iv) Surface manifestations and altered rocks; (v) Geology and Structural setting of the Eastern and Western Branches of the EARS (Tectonics, Volcanology and Geothermal Activity); (v) Basic Hydrogeology.

Ms. Lucy Njue on her presentation on Geothermal systems global perspective showcased a video on CalEnergy's geothermal powerplant as an introduction to geothermal energy. In the afternoon session Mr. Leakey Ochieng presented on Types and Classification of Rocks (Igneous/Sedimentary/Metamorphic) with emphasis on Igneous petrology/Volcanology and Surface manifestations and altered rocks. Later Mr. Marietta Mutonga presented on Geology and Structural setting of the Eastern and Western Branches of the EARS (Tectonics, Volcanology and Geothermal Activity). The day ended with a final presentation by Ms. Janet Suwai on Basic Hydrogeology. All in all day closed on a successful note as all the trainees were very satisfied and the trainers were also pleased by their interest in the topics and question.
The training commenced and ended on time with all trainees’ present. All scheduled lectures were adequately covered in interactive sessions.

The training focused on tools for geothermal resource mapping (geoscientific information) and an overview of geochemical and geophysical methods used in geothermal exploration and development. Specifically, the following topics were covered:

- Geographic Information Systems (GIS)
- Remote sensing
- Principles and application of geochemistry in geothermal resource exploration
- Use of Water, gas, and isotope geothermometry (Data integration, processing and interpretation); Case studies: Olkaria / Menengai or any other geothermal fields
- Overview of geophysical methods used in geothermal exploration
- Geothermal mapping using ground temperature measurements & Temperature gradient holes (TGH)
- Resistivity methods: (a) TEM; (b) Magneto telluric; (c) IP


Joseph Gichira (Geophysicist – GDC) gives a lecture on an overview of geophysical methods used in geothermal exploration during the 2nd IPCU-AGCE level 1 training on Geothermal Science and Technology at the GDC Nakuru Polo Centre training facility.
Day Three

The day covered geophysical methods in geothermal exploration, Seismics, data integration and development of a conceptual model of a geothermal system with examples of case studies and the role of environmental and socio-economic baseline studies in geothermal resources development.

**Geo-physics**

The trainees were well exposed to gravity and magnetic methods for geothermal resource exploration by Joseph Gichira with the take home message that the two methods are critical in structural mapping of a geothermal heat source, fractures/faults, potential drilling sites and recharge areas and they require less resources since they are relatively cheap with minimum field support.

For Seismic refraction and monitoring by Deflorah Kangongo, the trainees learnt the importance of seismic methods in geothermal exploration and development for determination of heat sources, mapping out zones of reservoir recharge and evaluation of existing reservoir properties. The active and passive source seismic methods were explored, and the lecture was concluded by Seismic data analysis and interpretation.

**Geophysical, Geological and Geochemical models of a geothermal system**

Geophysical data Integration, processing and interpretation was also covered in detail by Dr. Antony Wamalwa for gravity, magnetics, seismics, TEM and MT Data. Charles Muturia gave a lecture on geophysical models of a geothermal system and interpretation with case studies from Kenya (Northern Kenya) and Ethiopia (Tulu Moye and Alalobeda). In his presentation, the benefits of geophysical exploration were highlighted as important in locating a geothermal prospect, outlining the drilling fields and estimating the properties of a geothermal system.

Ms. Lucy Njue took the trainees through the geological model of a geothermal system whose main aim is to develop a detailed geological map of the project that should provide a critical input in the final conceptual model. Key areas of data for computation and synthesis of a geological model were studied. They included rock types and contacts, shape of the rock bodies and geological features, sequence and relative ages of rocks, marker horizons, permeability geothermal manifestations, weathering of rocks, depositional or magmatic flow features, general structure regional and local, focal mechanisms, folding, potential geohazards amongst others. Finally, the lecture ended with interpretation of a geological model.

The objectives, development and interpretation of geochemical models was also covered by Jeremiah Kipng’ok. It was interesting for the trainees to understand the aims of a geochemical model as determination of: temperatures of a geothermal system, origin of fluids, characterization of water types, upflow and outflow zones, NCG composition and characteristics, well sites and the most appropriate use of the resource etc. Case examples of geochemical models from Silali and Menengai geothermal fields were extensively discussed.

*Jeremiah Kipng’ok giving a lecture on geochemical model of a geothermal system.*
**Integrated geo-scientific studies: Conceptual model of a geothermal system and case studies.**

Raymond Mwakirani gave a summary of the data input of the different geo-sciences and significance. He elaborated to the trainees how the data is incorporated into a conceptual model and its relevance in determining the existence of a geothermal system specifically by definition of the heat source, permeability and reservoir temperatures.

**Environmental and socio-economic baseline studies (ESBS) for geothermal resource development**

Dr. Mutia, concluded the days training with a lecture emphasizing the need for baseline environmental studies as a yardstick in conducting future environmental impact assessment studies for proposed geothermal projects in line with most local and international regulatory and legal requirements. Methods of baseline environmental and socio-economic data collection and analysis were discussed. Anticipated geothermal resources development project impacts were studied and management options. The trainees were then taken through reporting of an ESBS study. In her interactive lecture, trainees were finally grouped into three and tasked to identify impacts of proposed projects and suggest mitigation/management measures. A case study of the arus-bogoria ESBS studies was presented for conclusion.

Trainees during a group assignment and presentation for ESBS class.

As a close of the day’s activities, trainees were given a brief field work coverage for the next day and take-home material for study in preparation for the fieldwork.
Trainees spent their day outdoors for a practical session, 25 km away from the GDC Polo Centre training facility at the Menengai geothermal field. The focus was on demonstration of various geoscientific investigation tools and methods for geothermal resources exploration, with the aim to acquit trainees with a firsthand field experience on the initial steps of geothermal resources development. The field excursion covered three areas, namely: the Geology of Menengai, Surface geochemistry of Menengai and Geophysical field demonstrations.

**Geology**
Ms. Lucy Njue took the trainees through an overview of the general geology of Menengai and the formation of the caldera while they observed first-hand the main geothermal surfaces manifestations in Menengai.

**Geochemistry**
Menengai geothermal field has few geothermal manifestations, which makes exploration using classical geochemical methods challenging. The few manifestations occur in the form of hydrothermally altered rocks and fumaroles. Mr. Jeremiah Kipngok demonstrated to the participants how to collect fluid samples from a fumarolic discharge.

**Geophysics**
Ms. Deflora Kangogo showed the trainees how to investigate the physicochemical properties of rocks and they can now differentiate what geophysical techniques/equipment are used to measure different aspects such as density, magnetic susceptibility, acoustic wave velocity and electrical resistivity. Geophysical field demonstrations showcased involved the following:

- Calibration of all geophysical equipment to be used
- Data acquisition through resistivity measurements – TEM, MT
- Data acquisition through gravity, magnetics, MEQ

Plate 4: Demonstration on use of Geophysical equipment to EEA trainees for exploration at the Menengai geothermal field, Nakuru Kenya.

**Environmental Baseline Data Collection**
Finally, Environmental baseline data collection was also covered by Ms. Rose Kiama for surface water, soil, vegetation, noise & air quality measurements and weather monitoring. Trainees were shown how to use the various different equipment for environmental baseline data acquisition including sound level meters, automatic weather stations, TDS-PH meters and sample collection for laboratory analysis of elements of environmental significance.
Trainees visited the Menengai geothermal project site laboratories situated 25 km away from the GDC Polo Centre training facility. The aim of the session was to give the trainees an overview of rock and fluid samples analyses at both the Geology and Geochemistry labs as well as on environmental monitoring practices.

**Rock sample analysis by Lucy Njue and geology lab team**

Ms. Lucy Njue (Geologist) and Ms. Carolyn Ndisha (Geology - technician) took the trainees through an overview of the thin section preparation, rock forming and alteration mineral identification, rock chemistry and alteration minerals including clay mineral analysis (XRD) and rock forming minerals/rock chemistry and clay mineral analysis.

**Fluid sample analysis by Jeremiah Kipngok and geochemistry lab team**

At the Geochemistry lab, the trainees were showed how various measurements like pH, Total Dissolved Solids (TDS) and Electricity Conductivity (EC) are done amongst other analyses. They also had an opportunity to see the functions of major analytical instruments i.e. the Ion Chromatograph (IC), Atomic Absorption, Spectrophotometer (AAS) and the Gas Chromatograph (GC) that are used for analysis of anions/cations, metals & gases respectively.

**Environmental Pollution Assessment & Monitoring: Meteorology, Air Quality & Noise Monitoring; Water Chemistry & Social Afforestation and Restoration (Field Work) demonstration by Rose Kiama**

**Meteorological Parameters Monitoring:** The trainees were shown the Automatic Weather Station (AWS) installed at the Menengai Lay Down area and its functions including collection of hourly weather data for key parameters including Rainfall Totals (mm), Air temperature (°C), Relative Humidity (RH) % and Wind Speed and Direction (m/s).

**Air Quality Monitoring:** Demonstration of Hydrogen Sulphide (H2S) gas and suspended particulate matter monitoring in air was done using a H2S analyzer and a dust analyzer (Haz Dust). The trainees were shown how to establish air quality monitoring sites depending on site activities. Data download from the monitors for analysis was also demonstrated.

**Noise Level Monitoring:** A hand held sound level meter was used to demonstrate noise level measurement. Demonstration was done on taking noise levels both downwind and upwind and also on factors to avoid and those to consider in noise measurements. Choosing of designated sites for noise monitoring where operations are ongoing or as required (Day and Night) was discussed.

**Water Quality/Effluent:** Trainees were shown how to locate surface water and effluent monitoring sites and elements of environmental significance for laboratory analysis were discussed.

**Social Afforestation and Restoration (Rehabilitation):** Trainees were given a tour to the tree nursery site at Menengai and told of the importance of having a tree nursery for raising tree seedlings; primarily to produce sufficient quantities of high quality seedlings and different tree species, to satisfy the ever rising need to conserve and restore the environment. The raised seedlings are used for Social Afforestation and Restoration of degraded areas at the project. The trainees were also shown a rehabilitated farm that was once a quarry for the project infrastructure development.
Day six of the Geothermal Science and Technology Training for trainees from EEA was concluded successfully. Trainees were taken through the drilling technology in geothermal resource exploration and development and borehole logging as detailed below.

**Drilling technology**
Drilling Engineer Abraham Khaemba gave a lecture on introduction to geothermal well drilling covering well design considerations, preparations before drilling commencement, basic functions of a rig & types of drilling rigs, drilling rig technologies, systems & components, the drilling program and personnel & camp management. Specialized services in drilling including highlights on directional drilling, stuck pipe and fishing, side tracking, well work overs and hydraulic fracturing were interactively discussed.

Sequentially, training on civil works including infrastructure and site preparation for geothermal well drilling followed by Peter Ole Kachuma (Civil Engineer). Trainees were able to understand how access roads, well pads and circulation ponds are constructed and maintained. Further, provision of water for drilling operations and domestic use was also covered.

Engineer Michael Kamau took the trainees through the actual process of geothermal well drilling with details on well design, drill string design, BHA, Bit technology, drilling fluids, cementing, vertical and directional drilling and HSE & challenges. Overall, Eng. Kamau summarized to the trainees all costs involved in drilling a geothermal well.

**Borehole logging**
Borehole geology including lithological descriptions of cutting and rocks recovered from wells during drilling was discussed by Marietta Mutonga as important in identification of rock formations, assessment of porosity and permeability, alteration temperatures, depth of casing and overall condition of a geothermal well. Sampling of cuttings at the rig, analysis, lithological descriptions and sample storage was covered.

Marietta also gave a lecture on hydrothermal alteration mineral studies i.e. their occurrence, analysis and contribution to geothermal resource explorations and development. Key points that the trainees took note of in this lecture was on the application of hydrothermal alterations in geothermal systems for the areas: geothermometry, permeability indication, thermal history, prediction of scaling and corrosion tendencies of a well, setting the production casing and an understanding of the nature of the reservoir.

Thereafter, the day was concluded with a lecture on downhole sampling of geothermal fluids (borehole geochemistry) by Jeremiah Kipngok. Drilling fluid returns to infer possible aquifers and production properties; well discharge chemistry to assess quality of steam and tendencies for scaling and corrosion and management and downhole sampling to determine the chemical properties of different aquifers feeding a geothermal well were well discussed. Finally, a summary on tracer tests using chemical tracers and radio tracers was presented as an important tool for studying well interference/connectivity.
Trainees went for a field visit at the Menengai geothermal project area, 25 km from the GDC Polo Centre training facility, Nakuru. Two areas were of main focus: an experience at a geothermal drilling rig led by Engineer Michael Kamau and borehole logging by Geologist Marietta Mutonga.

**An experience at a geothermal drilling rig**

Trainees were showed various infrastructural and drilling rig components associated with the Menengai geothermal drilling project; specifically: the drilling water supply system, rig move operations, different rig components, storage of drilling consumables, spares & tools management, cementing yard i.e. materials laydown area, motor vehicle workshop for fleet management, steam gathering system, KETRACO transmission line and a discharging geothermal well.

Trainees were very excited when they saw the massive geothermal infrastructural installations including the drilling rig and its components and operations at Menengai. They raised questions on how long the entire project development has taken including the capital costs and management of the operations in a fully Africanized set up. Key to note is that the trainees showed a great interest in the drilling simulator and cementing operations. They were advised of advanced courses on the same under the IPCU AGCE program.

Plate 1: Engineer Michael Kamau and Geologist Marietta Mutonga with the EEA trainees at Menengai geothermal project for practical sessions at a drilling rig and aspects of borehole logging
Practical experience on Borehole logging

Aspects of borehole logging including sampling and analysis were demonstrated. Trainees were taken around the eight groundwater boreholes that have been drilled by GDC for provision of potable water; the importance of ground water for drilling was well explained. It was notable that the boreholes are high yielding and hence their ability to sustain drilling operations for more than four rigs. The potable water is also of good chemical composition and therefore it doesn’t corrode drilling apparatus and can be used with other drilling additives such as bentonite to return drill cuttings to the surface.

Trainees were also taken to the mud tanks and shale shakers and shown how drilling fluids acted as a transport medium for the cuttings to the surface and the sampling points where samples are collected by the technicians.

The role of a geologist once the samples were collected, the preliminary analysis carried out and its importance in advising the drilling team on the casing depth was also demonstrated. Trainees had a chance to see the different casing sizes and were explained for the importance of each; the 1st two were mainly to protect ground water with the most important one being the production casing that is slotted to collect in the geothermal fluids. Finally the trainees were lucky to see an outcrop in one of the well pads, they appreciated its stratigraphy and were able to visualize the process of drilling through it.

The objectives of the day were met and trainees departed back to Nakuru town at 1600 hours.
Trainings interactively covered two main areas i.e. well testing & reservoir technology and health, safety and environment.

**Well testing and reservoir technology**
The role of reservoir engineering in geothermal resource assessment was elaborated. Hillary Mwawasi (Reservoir Management Engineer) gave a lecture on borehole logging and well testing and covered aspects of sub surface data measurements, flow rate, enthalpy and power output. Other functions of geothermal resource management including reservoir tests and analysis, reservoir volume, fluid characteristics, power potential, well bore and reservoir simulation, production field monitoring and management and well history data storage and archiving were discussed. Trainees also had a session with Hillary Mwawasi on evaluation of a geothermal reservoir potential and the lecture detailed reservoir assessment methods and processes. Volumetric assessment and numerical simulation case studies were also presented.

A lecture on monitoring and management of geothermal reservoirs was also given by Stephen Onyango (Reservoir Management Engineer). The lecture highlighted production and re-injection monitoring, reservoir pressure responses, discharge enthalpy from production fields, tracer tests and numerical modelling.

Trainees in a lecture session on volumetric assessment of geothermal reservoirs by Hillary Mwawasi

An in-house demonstration of various uses of reservoir engineering tools for borehole logging and well testing was also carried out.

**Health Safety and Environment**
In the afternoon session, the extensive process of Environmental and Social Impact Assessment and Audit (ESIA & EA) was well covered by Dr. Thecla Mutia. In the session Dr. Mutia discussed the need for ESIA studies for proposed geothermal projects, the governing legal frameworks at local and international levels, Scoping, impact analysis, mitigation and impact management, ESIA reporting, reviews and decision making by the competent environmental management authority. Trainees were taught the development of environmental management plans, implementation and follow-up through environmental audits in detail, as a crucial aspect of ESIAs for effective management of environmental performance and continuous improvement. Case studies of ESIA and Environmental Audit reports were presented and discussed.
Management of ecosystems around geothermal power plants was also discussed. Irene Cheptum (Meteorology Scientist) took the trainees through biodiversity conservation protocols for geothermal projects and gave highlights of a new ecosystem monitoring tool for management of geothermal project areas. She also explained the need for air quality and noise monitoring as important aspects of biodiversity conservation. Hydrogen sulphide gas and noise emission simulations using AERMOD software were also presented as management/mitigation initiatives.

Key hazards in geothermal development, industry incident statistics, safety standards and safety management systems as part of Occupational Safety and Health management were also covered by Mr. Patrick Oyugi.

The management of positive and negative socio-economic aspects of geothermal development was discussed by Carolyn Ekuwom (Community Liaison Officer), as a continuous component of the geothermal resources development project cycle. This is key for sustainable development and community acceptance of geothermal projects that mostly occur in close proximity to marginalised communities. Trainees were also taught the process of preparing an elaborate stakeholder engagement plan and its effective implementation with case studies from GDC North Rift geothermal projects.
Day ten of the EEA training on an introduction to geothermal science and technology has ended successfully, concluding Part I of the training on Exploration of geothermal resources. To assess the level of trainee knowledge acquired on basic geothermal resources surface exploration, specifically on integrated geo-scientific investigation and its contribution to location of target sites for geothermal wells drilling, trainees undertook a two-hour assessment test. The test covered geology, geochemistry, geophysics, well testing and reservoir technology, drilling and environmental management. All trainees’ performance was above average.

Thereafter, trainees gave a presentation to their instructors on the status of geothermal exploration in Ethiopia. Their interactive presentation gave highlights on the status of geothermal prospects and projects in Ethiopia, the process of development, sector players involved, strategic plans, IPPs, PPAs and licensing. In their presentation, Ethiopia plans to generate 50 MWe by the year 2020 and 3,500 MWe by the year 2030. The trainee’s management representative Mr Tesfaye Kassa therefore indicated that the training they were undertaking was timely and that they had acquired more knowledge, which would be vital in their ambitious development plans. He pointed out that the training was helpful to his team as a form of induction as they were relatively new in his directorate. He further indicated that EEA and Ethiopia shall seek support from Kenya and establish long term partnerships for assistance in their geothermal projects development.

Finally, trainees gave a vote of thanks appreciating GDC instructors and management and the entire IPCU-AGCE coordination to the training. All trainees were happy with the training and felt that the training objectives had been met, they indicated that they would return for specialized courses in the future. They were proud of the young GDC scientists and the knowledge and experience that they possessed, it is their hope that Ethiopia will follow suit and that they shall transfer and implement the knowledge gained in development of geothermal resources in Ethiopia. Ms. Lucy Njue and Jeremiah Kipngok of GDC gave a vote of thanks on behalf of all instructors and thanked the trainees for their interactive sessions and great enthusiasm that they showed during the course, they encouraged them to keep in touch.
Lastly Dr. Thecla Mutia, thanked all participants on behalf of GDC management and congratulated all trainees for performing well in their training sessions and assessment tests. She encouraged them to keep contacts with all their resource persons and maintain good networks that would be vital in future consultations whilst executing their duties.

EEA trainees and GDC instructors during the closing session of Part I on Exploration of geothermal resources at GDC Nakuru training facility.
The second part of the Geothermal Science and Technology Training commenced on 22nd August 2019 at the KENGEN facility-Olkaria Complex, Naivasha. The training is being facilitated under the auspices of Interim Project Coordination Unit (IPCU) of Africa Geothermal Center of Excellence (AGCE). Representatives of KenGen, GDC and Ethiopian Energy Authority trainees were among those present during the opening ceremony, which took place at the Lake Elementaita Boardroom.

Speaking during the opening ceremony, the Geothermal Development Director (GDD) represented by KenGen’s Resource Development & Infrastructure Manager welcomed the participants and guests to Olkaria and thanked the participants for having accepted to attend this training. He reiterated that Kenya delights in supporting the region in terms of Capacity building in the area of geothermal resource exploration and development and looks forward for continued participation in such initiatives. I urged the participants to go back home more informed about geothermal and be the champions who will promote this indigenous resource which is abundant in the region.
The first lecture of the training was on **Energy Landscape in Africa** tailored for the Geothermal Training on Science and Technology for Ethiopian Energy Authority by Dr. Meseret Zemedkun. This lecture focused on UN Environment being the lead organization that coordinates environmental matters within the United Nations system. The organization produces environmental assessments and analyses, norms, guidelines and methods for use by stakeholders looking for guidance on how to effectively manage the environment for their sustainable development and economic growth. The UN Environment Energy Programme main mission is to supports countries to improve energy efficiency and increase use of renewable energy as part of their effort to achieve low-carbon and climate resilient development.

**Overview of Utilization of Geothermal Energy** by Gideon Gitonga was the second lecture of the day. Types of utilization depends on the resource temperature and after drilling wells are tested to determine their output potential, nature of the reservoir and the best way to utilize the well. In Kenya, geothermal development is currently in three fields that is; Olkaria, Eburr and Menengai.

On the third lecture of the day Gideon Gitonga talked about **Geothermal Flash and Binary Power Plants**. Geothermal power plants can either be Single flash; Double flash; Binary power plants; Wellhead power plants. Power plants are majorly composed of Steam Supply Systems, Energy conversion, Cooling Systems and Gas extraction systems.

Peketsa Mangi was the fourth speaker of the day and gave a presentation on **Geothermal Project Management**. He started the lecture with learning objectives which were;

- Define a project and the triple constraints.
- Discover process groups, knowledge areas and their interactions.
- Appreciate the geothermal energy development phases.
- Understand the various concepts and dimensions of monitoring and evaluating projects.

Project management professionals recognize the triple constraints, which are **scope, cost and time** which plays a key role in the quality of the project.

**Financing Energy Sector Projects** was our last lecture of the day, facilitated by Peninah Ng’ethe. As of 2018 KenGen was 70% GoK owned with an Installed capacity of 1631MW, a revenue of US$350 million and an asset base of US$3750.
The trainees of the Ethiopian Energy Authority spent their day outdoors for a field trip around the Olkaria geothermal field. The objective of this trip was to equip the EEA trainees with a firsthand field experience to the Olkaria geothermal field and the daily operations in various geothermal power plants. The KenGen representatives and the EEA trainees toured three sections of the Olkaria Geothermal field; the viewpoint, Olkaria AU and the Olkaria 914.

**The Viewpoint:** Mr. Gideon and Mr. Gastone Odhiambo gave the EEA trainees an overview of the Olkaria II power plant, which was clearly visible from the viewpoint. Meandering of the steam pipes was one of the major concerns, where Mr. Gideon explained the reason behind the trend.

**Olkaria AU (4&5):** The plant operator gave the EEA trainees and the KenGen representatives a tour around the Olkaria AU power plant. He explained how the whole process begins from the 24 wells to the generation of electricity and supply of the electricity. Among the visited places included; the separator, the turbine room and the control room.

**Olkaria 914 Wellhead Unit:** At this station members were able to see the wellhead technology. The pilot plant of this project had an output of 5.5MWe.
Donor funded projects: Resettlement Action Plans

The first lecture of the day was done by Philip Barasa who took the EEA trainees through the topic. The objectives of this lecture were to understand what project appraisal entails and the resettlement process. At the end this lecture some of the conclusions made included;

- Community institutional arrangements ensures greater support of the project by Project Affected Persons
- Effective stakeholder management can bring about timely delivery of projects
- Outdoor meetings help to bring trust among Project Affected Persons and the project proponent
- ESIA should provide the mechanisms to interact with, and build up trust between Project Affected Persons

Licensing (prospecting, Exploration & Development) was our mid-morning lecture; EEA trainees gave their expectations as per the topic. The set objectives of this lecture were;

- Identify the various licensing requirements that are applicable to the geothermal prospecting, exploration and development in Kenya
- Administration of Licenses – The Kenyan Experience
- Types of Licenses
- Legal Framework
- Drilling permits required
- Compliance and Monitoring of the Licensing Procedures
- Standards and Guidelines of the Licensing Departments in Kenya
- Compare the Kenyan experience with that of Ethiopia in terms of Licensing requirements

For sustainable development of geothermal resource to be achieved, there is need to;

- Identify applicable legal requirements
- Track emerging legislation to prevent surprises
- Work in close liaison with regulators
- Develop & continually update the compliance matrix
- Carry out compliance audits

In the afternoon Licensing (Generation) lecture was covered. Mr. Philip Barasa expected the EEA trainees to identify the various licensing requirements that are applicable to geothermal project operation in Kenya and compare the Kenyan experience with that of Ethiopian in terms of licensing requirements. Mr. Philip Barasa took the trainees through the various regulatory bodies mandated to carry out compliance audits to enforce the provision of the respective regulations in term of licensing. Failure to comply could translate into high operation cost and ungovernable stakeholder issues.
Mr. Philip Barasa explaining some of the Regulatory acts that governs geothermal operations.

EEA trainees during their group discussions
The lecture on Bankable documents for geothermal projects was done by Ann Kiburi. This lecture entailed the substantial risk related to finding and developing the geothermal resource, mainly at the initial stages of a project, implying extremely high value at risk- we estimate a cost of US$ 6.5 Million per well. High upfront capital for the drilling and exploration phases, where most of the risk is undertaken. Significant financial commitment needs to be made before the characteristics of the resource can be fully known.

Conclusions made on this lecture were:

1. It is important to carefully plan and organize the project preparation to ensure that the right information is available at the right time and presented in correct manner to help make the right decision
2. The economy of geothermal projects is sensitive and errors in resource assessment and project design can be very costly
3. Systematic Planning can help avoid pitfalls that jeopardize project success potential
4. Feasibility studies are necessary not only to list the outcome of exploration studies, engineering design and project cost, but also to address risks and present scenarios and development strategy that both optimizes project profitability at same time as minimizing project risk.

Costing of energy projects was Ann Kiburi’s last lecture. Energy projects are costed through a technique called-Life cycle cost analysis. The method evaluates the costs and benefits associated to the project taking into account the time value of money. Cost and Benefits are the main consideration in life cycle cost analysis.

PRESENTATIONS BY EEA TRAINEES

Case team 1 - Licensing team (Alemtsehay Desaleng Hundie)

1. **Introduction to geothermal development in Ethiopia:** Started in 1969 covering an area of about 150000 sq. km with a prospectus of about 24 wells
2. **Geothermal Legal Framework:** Published Proclamation/Regulations and Draft Regulations
3. **Types of licensing:** Grade one Geothermal resource license >Electricity Generation; Grade two geothermal resource licenses>Direct use
4. **Requirement for Grade One license:** Reconnaissance license, exploration license and well filed development and use license
5. **Application for Grade two Geothermal Resource License:** Proof of registration to conduct business in Ethiopia

Case team 2-compliance and monitoring team (Eyasu Solomon Abebe)

Key notables of the Status in Ethiopia

1. Institutional Setup
2. The Role of Compliance & Monitoring case team
3. History of Surface Exploration
4. History of Deep Exploratory well drilling and testing.
5. History of Power Plant Construction and Operation
6. History of Private Sector Participation (IPPS)
7. Status of Geothermal Development in Ethiopia
8. Stakeholder Engagement
9. Geothermal Legal framework
Mr. Eyasu Solomon Abebe the team leader gave the following remarks on the conclusion part: Despite huge, quality geothermal resources in Ethiopia, development is still at early stage. The main reasons may be related to: institutional set ups, capacity, management, planning, coordination etc.

**Geothermal Spa Visit**

The EEA trainees accompanied by Mr. Gaston toured the geothermal spa in the afternoon.

Trainees enjoying the afternoon at the Geothermal Spa
EEA Trainees Presentations

Licensing team members
1. Alemtsehay Desaleng - Team leader
2. Mekdes Yihenew Alem
3. Selamawit Dagnachew
4. Ayele

Their presentation basically entailed:
- Need for dedicated geothermal legal framework
- Ethiopian Energy Authority – geothermal resource regulator
- Two grades of resource – for electricity & for heat
- License may be given on a competitive basis
- Three types of Licenses
  - Reconnaissance
  - Exploration
  - Well Field Development and Use

Compliance and Monitoring team members
1. Eyasu Solomon Abebe - Team leader
2. Fikre Feleke Lema
3. Habtamu Abatneh
4. Teleksaw Habtamu
Initial setup of the Ethiopian Energy Authority

Recently studied geothermal development models and set ups for Ethiopia
Proposed models by JICA in 2015, in relation to Master Plan Studies for Geothermal Development

Under the present pricing policy of Ethiopia,
Viable business models:
- Model-C (marginal)
- Model-D
- Fully Public

Source: Jica Study Team
Mr. Alfred Oseko gave a lecture on Kenyan National Energy Development Strategies. This lecture majorly entailed; Kenya’s Development Agenda, Overview of Kenyan Electricity Sub-sector, Energy Sector Plans and Energy Mix.

PPA Negotiation, Risk Mitigation & Various Development Models was a lecture tackled by Mr. Alfred Oseko. Major outlines on this lecture were:
- What is a PPA and Bankability?
- Risks inherent in PPA and Project Environment
- Social, Economic and Political Factors
- Environment Factors
- Tariff Development and Revenue requirements

Legislation/Acts Impacting on the Energy Sector & Stakeholder Mandates lecture was done by Kenneth Wamwangi. Major focuses on this topic were;
- Current legislations impacting of the energy sector
- National Energy Sector Entities
- Provisions of the Energy Act 2019
- Stakeholders & their Mandates
The first presentation of day six was from Mr. Denis Muya on Transmission and Distribution (The Kenyan Experience). The overview of the Kenyan electricity supply system involves; Players, Regulations, Statistics, Challenges.
Overview of the Kenya Electricity transmission system

CHALLENGES OF THE DISTRIBUTION SYSTEM IN KENYA

- Use of substandard distribution equipment
- Inadequate Funding for maintaining and upgrading infrastructure (high costs of generation limits funds available)
- Monopoly of retail side
- Vandalism of power equipment (transformers mostly)
- High connection fee over US$ 400 (due to high costs)
- Spread out population distribution in the Rural Areas, lack of centralised settlements in rural areas
• Poor supplies during rainy season

**Development of Kenyan Electricity Supply System**

• Connection growth from 10% in 2004 to >50% in 2018

• Reduction in system losses

• Reliability

**FUTURE PLANS**

• Licensing of retailers and distribution service operators
• Net metering
• Universal access
• Electricity trading

In the afternoon, the EEA trainees gave a presentation on **Gaps in Kenya and Ethiopian Geothermal Licensing**. The major outlines on this lecture were:

1. Licensing issuance
2. License period
3. Classification of license
4. PPA agreement
5. Marketability
6. Environmental baseline studies
7. Transmission, Generation and Distribution
8. Institutional setup
9. Capacity building capacity
10. Land ownership
11. Geothermal been a base load
The EEA trainees spent the morning hour in their respective groups doing the group work exercise (Project Work) given by Alfred Oseko and Kenneth Wamwangi.

Plate 7.1: EEA Group work Discussions

Mr. Ronoh Kibet gave a presentation on **project management** in the afternoon. Project Management is the discipline of carefully planning, monitoring & evaluating of resources to achieve specific goals and meet Specific Success criteria.

The project evaluation and review technique (PERT) Decomposition

- Optimistic time (O)
- Pessimistic time (P)
- Most likely time (M)
- Expected time (TE)

\[ TE = \frac{(O+4M+P)}{6} \]

Plate 7.2: Mr. Ronoh Kibet presenting on Planning of Geothermal Projects.
**EEA Group work Discussions (Project work)**

The day was spent doing the project work by the EEA trainees in their respective groups. Case team I focused on compliance and monitoring and case team II tackled Geothermal Licensing in Ethiopia.

![Plate 8.1: EEA trainees during their project work](image)

**Day Nine**

The EEA trainees accompanied by Mr. Gideon Gitonga spent the day on a field visit to Orpower power plant and Oserian firm.

**Orpower 4**

Mr. Hillary the Mechanical Engineer at Orpower 4 took the Ethiopians energy authority trainees and the KenGen representatives an overview of the plant operations and the plant systems. Members present came across a binary power plant and its operations as seen earlier during a presentation on Power plant systems by Mr. Gideon Gitonga. This power plant uses a hydrocarbon known as pentane during generation of electricity.
Later the EEA trainees accompanied by Gideon Gitonga toured the Oserian firm. Mr. Apollo the firm manager showed the various ways Oserian firm was using the geothermal steam. The various ways included:

1. Electricity generation
2. As a heat exchanger in greenhouses to boost in flower growth

Mr. Apollo also showed the EEA trainees the solar power plant which was at a capacity of 1MW
The day ended with a **graduation ceremony** for the EEA trainees where awarding of certificates was done. The ceremony was graced by EEA trainees, Joseph Kebu, Geothermal development director Mr. Mangi, Gaston Odhiambo Mr. Peter Ndirangu the training coordinator and Other guests.