DOCUMENT: Education Curriculum for skills appraisal program

<table>
<thead>
<tr>
<th>REF:</th>
<th>Title: GEOTHERMAL RESOURCES HARNESSING AND DEVELOPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Date:</td>
<td>Issue: 1</td>
</tr>
<tr>
<td>Revision: 0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prepared By:</th>
<th>Signed by:</th>
<th>Approved By:</th>
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</thead>
<tbody>
<tr>
<td>Chairperson, Mining, Materials and Petroleum Engineering Department</td>
<td>Dean, College of Engineering and Technology</td>
<td>Vice Chancellor and Chairperson, University Senate</td>
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1.0 Introduction

The demand for energy resource that is environmental friendly, particularly geothermal energy has been on the increase in the past decades. Geoscientists have continued to play a noble role in unveiling prospective terrains for this energy resource. Adequate knowledge and technical skills concerning geological settings and exploration techniques is paramount in unveiling geothermal resources. Furthermore, comprehensive development of this resource requires well trained manpower to address effective management of geothermal reservoir and environmental impact caused, amongst other constraints. It is on this basis that this short program has been developed. The program is intended to upgrade technical skills necessary for optimal harnessing of geothermal resources so as to meet electrical power demand by the nation. Developing such short programs is in line with the vision and mission of the Jomo Kenyatta university of Agriculture and Technology.

The program consists of 13 course units which will be offered in a total of 41 modules. The delivery will be reinforced by learning sessions in which audio vision aids will be used to simulated realities of the geothermal industry. Furthermore, discussion forums and an academic visit to geothermal sites and a geothermal power plant have been factored in the program. The visits, when accomplished, will enable learners to cement the realities of concepts acquired at the leaning center. The developed program will be able to achieve its goals by the end of 4 weeks thereby covering 146 contact hours for the participants. Targeted learners for the program are workers in the geothermal industry. On successful completion of the program, each participating worker will be awarded a certificate for skills appraisal which will enhance curriculum vitae of the worker thereafter.

1.1 Vision and Mission of the University

1.1.1 Vision
To achieve global excellence in Training, Research and Innovation for development.

1.1.2 Mission
To offer accessible quality training, research and innovation in order to produce leaders in the fields of Agriculture, Engineering, Technology, Enterprise development, Built Environment, Health sciences, Social sciences and other applied sciences to suit the needs of a dynamic world.

1.2 Program Purpose
This concise academic program has been developed by the Department of Mining, Materials and Petroleum Engineering. It is intended to provide adequate knowledge and practical skills to enhance effective delivery of resource persons in the geothermal energy sub-sector.
1.3 Program Philosophy
This program is an academic train loaded with knowledge, technical skills and positive attitudes necessary for exploring, harnessing and managing geothermal resources to meet the demand by our economy for renewable energy.

2.0 Target Groups and Justification

2.1 Target Groups
Workers in geothermal industry who are enlisted as technicians and have an academic background in line with sub-section 6.0.

2.2 Justification
Economic development of a country becomes sound when there is adequate supply of electrical energy to all sectors. It is preferred that the energy supplied be friendly to the environment, a preference that geothermal power fits well. Thus, upgrading skills for workers in geothermal energy sub-sector to enable the workers perform exemplary in very much in order. This program precisely addresses this perception in fulfillment of the vision and mission of the university. Furthermore, upgrading technical skills for workers in the industry is in line with the university’s contribution towards the country’s goals for vision 2030 and beyond. The program has been designed to equip the learners with relevant technical knowledge and managerial skills that are essential for competent delivery on the geothermal power platform. Weighting and mode of teaching of the units to be covered will be in line with the expectations of the academic policy of the Jomo Kenyatta University of Agriculture and Technology. Indeed, contact hours for the units of the program are as follows:

<table>
<thead>
<tr>
<th>Cluster</th>
<th>No. of Units</th>
<th>Contact Hours</th>
<th>Percentage Contact Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geological Sciences</td>
<td>3</td>
<td>28</td>
<td>19.18</td>
</tr>
<tr>
<td>Engineering Sciences</td>
<td>7</td>
<td>48</td>
<td>32.88</td>
</tr>
<tr>
<td>Complementary Studies</td>
<td>2</td>
<td>20</td>
<td>13.70</td>
</tr>
<tr>
<td>Discussions</td>
<td>-</td>
<td>12</td>
<td>8.22</td>
</tr>
<tr>
<td>Slides/Video shows</td>
<td>-</td>
<td>12</td>
<td>8.22</td>
</tr>
<tr>
<td>Industrial/Site visit</td>
<td>1</td>
<td>16</td>
<td>10.95</td>
</tr>
<tr>
<td>Report writing and submission</td>
<td>1</td>
<td>10</td>
<td>6.85</td>
</tr>
<tr>
<td>TOTAL</td>
<td>13</td>
<td>146</td>
<td>100</td>
</tr>
</tbody>
</table>
3.0 Program Objectives

This short program in geothermal resources was developed to enable a participant;

1. Be equipped with knowledge and technical skills that are necessary for understanding distribution of geothermal energy resources based on controls of plate tectonics, geologic structures, and rock types of volcanic mode of formation,
2. Understand classification of geothermal systems that is done according to temperature, modes of heat flow, and geologic setting,
3. Gain an understanding of modern techniques used to explore, evaluate, and develop geothermal resources,
4. Develop skills applicable to effective management of geothermal investments considering various factors particularly, geological suitability, economic viability and environmental impact to be caused by the investment,

4.0 Expected General Learning Outcomes

Upon successful completion of the program, the participant will be able to:

1. Characterize geologic settings of geothermal resources by making use of knowledge learned on plate tectonics, rock types, and geologic structures,
2. Classify geothermal systems according to modes of heat flow while capturing, conductive and type of heat source,
3. Demonstrate an understanding of geological, geochemical, and geophysical techniques that are used to identify geothermal potential geological terrains,
4. Conduct studies on existing geothermal investments to understand their geotectonic settings and economic performance as well as mitigation measures put in place due to environmental impact issues.
5. Practice effective management of natural resources with emphasis on geothermal investments if given an opportunity to apply the learned managerial skills.

5.0 Duration and Pattern of the Program

The program will be offered in a duration of Four (4) weeks.

6.0 Entry Requirements

Workers in geothermal energy sub-sector who have at least secondary school level of education up to form Four (4) will be eligible for the program.

7.0 General Regulations

The academic policy of Jomo Kenyatta University of Agriculture and Technology shall apply.
8.0 Use of Audio-visual Aids and Industrial visit

(a) Sessions for Slide /Video shows:
(i) To bring real activities of the field and geothermal industry to a classroom environment,
(ii) To utilize the power of audio-visual teaching aids in imparting knowledge to learners,
(ii) Enable participants appreciate wonders of nature and ongoing industrial processes without being physically on geological sites or industrial scenes captured.

(b) Industrial/Site visit:
(i) To enable participants confirm application of theoretical concepts learned to real practice in the industry, particularly on energy conversion and production processes,
(ii) To enable participants confirm field existence of geological features, structures and natural resources with a bias towards visiting sites of natural waters of low enthalpy and geothermal power plant.

9.0 Mode of delivery and instruction materials
Departmental lecturers and invited professionals will adopt one or a combination of any of the following methods with preference to use of power point presentations:

<table>
<thead>
<tr>
<th>Mode of delivery</th>
<th>Instruction materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>Handouts in form of hard and soft copies</td>
</tr>
<tr>
<td>Assigned reading of relevant materials</td>
<td>Power point presentation on screens</td>
</tr>
<tr>
<td>Audio-visual presentations</td>
<td>Overhead projector presentations,</td>
</tr>
<tr>
<td>Group discussions</td>
<td>Audio-visual presentation on screens and speakers</td>
</tr>
</tbody>
</table>
### 10.0 Course Units Structure

<table>
<thead>
<tr>
<th>Course Unit Title</th>
<th>Module Title</th>
<th>Time (Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GT 01:</strong> Petrology and Geological Mapping</td>
<td>GT 01/M1: Mineral Physical Properties</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 01/M2: Rock Types and Textures</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 01/M3: Hydrothermal alteration</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 01/M4: Plate tectonics and Volcanology</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 01/M5: Structural geology and Geothermal Activity</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>GT 01/M6: Types of Geothermal systems</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 01/M7: Geological mapping and Tools</td>
<td>2</td>
</tr>
<tr>
<td><strong>GT 02:</strong> Geophysical Exploration Methods</td>
<td>GT 02/M1: Overview of geophysical exploration methods</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 02/M2: General exploration strategy</td>
<td>4</td>
</tr>
<tr>
<td><strong>GT 03:</strong> Geochemistry of Geothermal Systems</td>
<td>GT 03/M1: General considerations</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 03/M2: Exploration using Soil Geochemistry</td>
<td>4</td>
</tr>
<tr>
<td><strong>GT 04:</strong> Fundamentals of Drilling Technology</td>
<td>GT 04/M1: Rotary drilling and Drilling Fluids</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 04/M2: Casing and Cementation</td>
<td>4</td>
</tr>
<tr>
<td><strong>GT 05:</strong> Heat Flow and Thermodynamics of Geothermal Resources</td>
<td>GT 05/M1: Geology and heat architecture of Earth’s interior</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 05/M2: Controls on subsurface flow of geothermal fluids</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 05/M3: Concepts of Thermodynamics</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 05/M4: Physiochemical properties and Wall rock alterations</td>
<td>2</td>
</tr>
<tr>
<td><strong>GT 06:</strong> Heat Flow Measurements of Geothermal Steam Fields</td>
<td>GT 06/M1: Overview of heat generation</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 06/M2: Heat flow measurements</td>
<td>4</td>
</tr>
<tr>
<td><strong>GT 07:</strong> Fundamentals of Measurements and Process Control</td>
<td>GT 07/M1: Measurement systems</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>GT 07/M2: Process control</td>
<td>6</td>
</tr>
<tr>
<td><strong>GT 08:</strong> Geothermal Reservoir Management</td>
<td>GT 08/M1: Management Aspects</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 08/M2: Monitoring of Geothermal Activities</td>
<td>2</td>
</tr>
<tr>
<td>Course Unit Title</td>
<td>Module Title</td>
<td>Time (Hrs)</td>
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<tr>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>GT 09: Geothermal Power plant</td>
<td>GT 09/M1: Components of Power Generation System</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 09/M2: Power Generation Technical Concerns</td>
<td>4</td>
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<tr>
<td>GT 10: Geothermal Energy Utilization</td>
<td>GT 10/M1: General aspects of utilization</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 10/M2: Consumers of geothermal energy</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 10/M3: Geothermal energy conversion system</td>
<td>2</td>
</tr>
<tr>
<td>GT 11: Environmental Impact and Assessment</td>
<td>GT 11/M1: Environmental considerations</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 11/M2: Environmental Impact</td>
<td>2</td>
</tr>
<tr>
<td>GT 12: Geothermal Economics, Project</td>
<td>GT 12/M1: Nature and scope of economics</td>
<td>2</td>
</tr>
<tr>
<td>management, and funding of geothermal</td>
<td>GT 12/M2: Project Scope</td>
<td>2</td>
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<tr>
<td>development</td>
<td>GT 12/M3: Project Analysis</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 12/M4: Project management Principles</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 12/M5: Geothermal Project cost and financing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 12/M6: Planning and management of geothermal projects phases</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 12/M7: Project handover, closeout and reviews</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GT 12/M8: Project Funding</td>
<td>2</td>
</tr>
<tr>
<td>GT 13: Field Excursion and Power Plant</td>
<td>GT 13/F1 - Fieldwork Practice</td>
<td>8</td>
</tr>
<tr>
<td>Visit</td>
<td>GT 13/F2 - Power Plant Visit</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>GT 13/L1 - Report writing</td>
<td>10</td>
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**Complementary Sessions**

<table>
<thead>
<tr>
<th>Slides/Video Shows</th>
<th>6 no. 2hrs/session</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion</td>
<td>6 no. 2hrs/session</td>
<td>12</td>
</tr>
</tbody>
</table>

**TOTAL** 146
11.0 COURSE UNITS DETAILS

Course Unit Title: GT 01: Petrology and Geological Mapping

Contact Time: 16 Hours

Course Unit Purpose
This course unit is intended to equip a participant with knowledge for distinguishing rocks based on textural properties and physical properties of minerals that are dominant in rocks dealt with. The participant will also be able to appreciate the significance of knowing natural features that indicate occurrence of geothermal activities for the purpose of identifying suitable sites to be investigated in details.

Expected learning outcomes
At the end of this course unit the participant should be able to:

a) Describe physical properties of rock forming minerals that influence textural and petrophysical characteristics of rocks in which the minerals are dominant,
b) Describe common rock types based on textural properties as seen in hand specimens with emphasis on igneous rock formations,
c) Describe features caused by hydrothermal alterations while focusing on effects of low enthalpy waters in a geothermal environment,
d) Explain magmatic processes that occur at plate boundaries while focusing on types of volcanic centers that are generated,
e) Describe geological structures that are associated with movement of geothermal fluids while capturing features that manifest geothermal activities in the field,
f) Describe the thermodynamics of geothermal systems based on structural controls, mode of formation and source of heating,
g) Explain procedures used to geologically map proposed geothermal sites while capturing mapping techniques, data collection interpretation and reporting procedures.

Course description
Module 1: GT 01/M2: Mineral Physical Properties
- Typical rock forming minerals
- Physical properties of major rock forming minerals

Module 2: GT 01/M1: Rock Types and Textures
- Igneous Rocks: Formation, textural characteristics
- Sedimentary rocks: Formation, textural characteristics
- Metamorphic: Formation, textural characteristics

Module 3: GT 01/M3: Hydrothermal alteration
- Primary and secondary minerals
- Mineral paragenesis and geothermometers

Module 4: GT 01/M4: Plate tectonics and Volcanology:
- Structure of the earth
- Plate boundaries: convergent, divergent, shear and features associated with each boundary.
- Types of eruptions and volcanic centers
Module 5: GT 01/M5: Structural geology and Geothermal Activity

- Structural controls and fluid flux
- Recharge mechanisms
- Geothermal manifestations and their relationship with geological structures

Module 6: GT 06/M6: Types of Geothermal systems

- Heat content: Low enthalpy, medium and high enthalpy systems.

Module 7: GT 07/M7: Geological mapping and Tools

- Planning of field work, mapping tools,
- mapping techniques, sample collection,
- Interpretation of field data, Reporting.

Recommended Textbooks for reading

3) Iddings, J.P. (2012). Igneous Rocks: Composition, Texture and Classification, Description and Occurrence, Volume 2, 804 p, Published by Ulan Press, ASIN: B009Q3Y8PK.
Course Unit Title: **GT 02: Geophysical Exploration Methods**

**Contact Time:** 6 Hours

**Course Unit Purpose**
This course unit is intended to provide the participant with knowledge and skills that are applied in geophysical exploration of sites that are potential for geothermal resources. The participant will also be able to appreciate the important role of geophysical techniques in geological interpretation of a site that could be economically viable which then aids in design of drilling systems.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:
a) Demonstrate an understanding of concepts in geophysics that are currently applied in exploration of geothermal prospects with emphasis on gravity, magnetic, electro-magnetics and seismic for determination of selected phenomena,
b) Describe geophysical anomalies for selected geophysical survey techniques that apply to geothermal prospecting,
c) Interpret basic geotechnical structures for surveyed strata of a geothermal prospect based on geophysical results obtained from existing geothermal establishments.

**Course description**

**Module 1: GT 02/M1 - Overview of geophysical exploration methods**
Gravity, magnetics, geo-electrics for Schlumberger arrays, magnetotellurics, including controlled source auto-frequency Magneto-Tellurics and transient electro-magnetics, Self-Potential, micro-seisims.

**Module 2: GT 02/M2 - General exploration strategy**

**Recommended Textbooks for reading**


Course Unit Title: **GT 03: Geochemistry of Geothermal Systems**

**Contact Time: 6 Hours**

**Course Unit Purpose**
This course unit is intended to equip the participant with knowledge in understanding the occurrence of different geochemical elements in geothermal fluids that pose danger to steam piping systems and environmental health thereby requiring their prompt extraction. The participant will also be able to appreciate the role of geochemistry in identification of hazardous elements in natural fluids thereby requiring mitigation measures to be incorporated at project planning stage.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Explain the procedures used to determine typical chemical constituents found in geothermal fluids while addressing distribution of the constituents and effects the constituents pose to the fluids in which they are dominant,

b) Explain the presence of geothermal constituents as an indication of possible geothermal potential for a terrain based on analytical results obtained from soil geochemistry, gas thermometry and vapor contaminants,

c) Interpret geochemical data for developed geothermal prospects focusing on geochemistry of the fluids, surface manifestations that were encountered and corrosive processes in action.

**Course description**

**Module 1: GT 03/M1 - General considerations**
Typical associated chemical elements, sampling techniques, analytical methods. **Geothermal systems**: compositional source, distribution of geothermal fluids, effects of boiling, mixing and condensation to the composition of water, reservoir condition, behaviour of gas and stable isotope in geothermal systems,

**Module 2: GT 03/M2 - Exploration using soil geochemistry**
Assessment of scaling formation, corrosivity in production pipes. **Geothermal system gasses**: CO₂, H₂, He, Ar, etc., occurrences, application in a geothermal system, Gas geothermometry; source of geothermal fluids as assessed from gas content. Vapor dominated geothermal system. Geochemical information for existing geothermal investments.

**Recommended Textbooks for reading**


Course Unit Title: **GT 04: Fundamentals of Drilling Technology**

**Contact Time:** 6 Hours

**Course Unit Purpose**
This course unit is intended to provide a participant with technical knowledge for understanding of the working of geothermal drilling systems with emphasis on rotary system, drilling fluids used, and engineering aspects for casing design, and cementation that leads to drilling completion. The participant will also be able to appreciate the importance of implementing drilling designs that factor in geotechnical and engineering constraints for optimal performance.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Describe operations involved in circulating fluids and mud in Rotary drilling works,

b) Describe casing and cementation technique as applied to drilling while capturing associated field problems and interaction of hydrothermal fluids with pipe materials,

c) Demonstrate an understanding of typical cases of developed geothermal drilling projects that utilize rotary drilling technology and allied instrumentation.

**Course description**

**Module 1: GT 04/M1 - Rotary drilling and Drilling Fluids**
Rotary drilling: Rotary drilling equipment, equipment operation, precautions, core recovery and preservation, transportation, storage. **Drilling Fluids:** Drilling fluid, Functions, Types, compositions, Properties of mud, Field test, Rheology, Additives and contamination, Selection of drilling fluids and mud, Conditioning equipment,

**Module 2: GT 04/M2 - Casing and Cementation**
Casing: Functions, types, API grades properties of casing, Threads and couplings, Functions, classification of cement, Strength retrogenion, Cement: Cement additives, Methods of cementation, Equipment accessories, Field problems pertaining to cementation job, interaction of hydrothermal fluids with drilling pipes.

**Recommended Textbooks and journals for reading**


Course Unit Title: **GT 05: Heat flow Patterns and Thermodynamics of Geothermal Systems**

**Contact Time: 8 Hours**

**Course unit Purpose**
This course unit is intended to provide a participant with knowledge for understanding heat flow patterns that develops in a geothermal reservoir based on thermodynamics concepts. The participant will also be able to appreciate the significant role of heat flow patterns in effective management of reservoir parameters.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Describe heat flow patterns using heat transfer concepts that apply to architecture of the earth considering composition and discontinuity structures present in different geological settings,
b) Describe geological structures that influence the distribution of heat regimes in different rock types,
c) Describe controls that affect subsurface flow of geothermal fluids capturing geotechnical parameters inherent in the host rocks constituting a geothermal terrain,
d) Demonstrate an understanding of essential thermodynamic laws that apply to physical behaviour of matter,
e) Determine thermodynamic parameters that apply to production of geothermal fluids considering physical and chemical properties of low enthalpy fluids,
f) Explain effects of steam interaction with wall rocks of geothermal terrains and depositional compounds generated based on thermodynamic concepts

**Course description**

**Module 1: GT 05/M1- Geology and heat architecture of Earth’s interior**
Heat of the earth’s interior: Earth’s compositional physical makeup, sources of heat, heat transfer methods, Rayleigh number, and impact on surface heat flow distribution, Geologic controls on heat energy; Rock types, geological structures, structural Influence on the distribution and types of geothermal resources.

**Module 2: GT 05/M2- Controls on subsurface flow of geothermal fluids**
Roles of primary and secondary porosity, permeability, Influence of rock types and structures on porosity and permeability. Power output as a function of mass flow rate and heat content of geothermal fluid.

**Module 3: GT 05/M3- Concepts of Thermodynamics**
Module 4: GT 05/M4- Physiochemical properties and Wall rock alterations
Physical and chemical characteristics of geothermal systems; Essential thermodynamic concepts, Thermodynamic considerations of water and fluid chemistry, Wall rock alterations; mineral deposition associated with liquid and vapor-dominated geothermal systems, Typical geothermal resources exhibiting effects of thermodynamics.

Recommended Textbooks for reading
Course Unit Title: GT 06: Heat Flow Measurements of Geothermal Steam Fields

Contact Time: 6 Hours

Course unit Purpose
This course unit is intended to equip a participant with technical knowledge for understanding methods that are used to measure temperature of a geothermal reservoir during exploration and during power production stages. The participant will also be able to appreciate the significant role of temperature measurement methods that yield data which is incorporated in reservoir management for optimum performance in the competitive business world of green energy exploration and development.

Expected learning outcomes
At the end of this course unit the participant should be able to:

a) Describe the geothermics petrographic parameters that affect temperature status of a geothermal reservoir considering the earth’s interior structure and thermodynamics qualifiers of heat flow,

b) Demonstrate an understanding of methods used to measure heat flow in a geothermal reservoir during site investigation and exploitation stages.

Course description

Module 1: GT 06/M1 - Overview of heat generation
Thermal structure of the earth, basic theory of heat flow in shallow earth, Geothermics petrographic parameters; thermal conductivity, heat capacity and radiogenic heat productivity, Enthalpy systems; low, intermediate, high

Module 2: GT 06/M2 - Heat flow measurements
Geophysical methods for survey stage: Thermal methods; Conduction, Convection, Radiation, Electrical resistivity methods: Affecting parameters; porosity, temperature, Rock alteration ,saturation, salinity, lithostatic and fluid pressure, Dc methods; Schlumberger sounding, Dipole sounding or profiling, Head-on profiling, TEMP method, TM method, SP method, Wellbore methods: concepts; Heat Flux Vector, Conservation Equation, well bore flow influx sensors.

Recommended textbook and proceedings for reading
Course Unit Title: GT 07  
Fundamentals of Measurement and Process Control

Contact Time: 12 Hours

Course unit Purpose
This course unit is intended to enrich a participant with knowledge and technical skills for understanding the role of measurement and process control in drilling and extraction of geothermal fluids. The participant will also be able to appreciate the role of instrumentation in utilization of physical parameters for controlling reservoir processes when harnessing geothermal resources.

Expected learning outcomes
At the end of this course unit, the participant should be able to;

a) Explain physical parameters that are captured during measuring processes to control the thermodynamic condition of geothermal reservoirs with emphasis on temperature and pressure, then describe construction components of a simple typical measurement system that can be used in a geothermal reservoir,

b) Describe the performance characteristics of a typical geothermal measurement system while keeping in mind concepts of process control, standard process symbols and allied illustrations,

c) Explain types of measurement errors that can arise in measurement and control processes and sources of technical noise in typical measurement systems,

d) Select appropriate techniques and devices for realizing a computer-based measurement system and evaluate the effectiveness of the devices selected,

Course description

Module 1: GT 07/M1: Measurement systems
Elements of a measurement system: typical Sensors and actuators; temperature sensors, pressure sensors, electric motors, and piezoelectric actuators, working principles, Transducers: temperature transducers, pressure transducers, displacement transducers, Signal processors: amplifiers/attenuators, linearizers, filters, ADCs and DACs, Performance characteristics: accuracy, precision, sensitivity, linearity, dead time, rise time, settling time, Measurement errors and noise: types, sources, mitigation, instrument calibration, measurement validity and reliability, Measurement systems found in geothermal energy exploration and exploitation: temperature measurement, pressure measurement, level measurement, flow measurement,

Module 2: GT 07/M2 - Process control
Process control concepts: measuring, comparing, computing and correcting, Computer-based measurement systems: practical considerations in adding computers to measurement systems, upscaling or downscaling of raw analogue input and output signals based on use of operational amplifiers, potentiometers, electromagnetic interference, Control loops: open and closed, Process control symbols and diagrams: process piping, major equipment items, valves, Process control systems: programmable logic controllers (PLC) and supervisory control and data acquisition systems (SCADA).
Recommended textbooks for reading


Course Unit Title: **GT 08: Geothermal Reservoir Management**

Contact Time: 4 Hours

**Course Unit Purpose**
This course unit is intended to equip a participant with technical knowledge for understanding principles and processes for effective management of a geothermal plant that guarantees safe and optimum performance of the plant. The participant will also be able to appreciate the importance of performance monitoring of a geothermal plant which gives the operators a timely chance to detect challenges that arise and take necessary corrective measures.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Demonstrate an understanding of factors that contribute to effective management of geothermal reservoirs capturing surface manifestations,

b) Explain performance monitoring as applied to ground water that is associated with geothermal fluids considering sustenance in productivity of natural resources,

c) Explain monitoring activities undertaken by typical geothermal investments that are currently in operation on the globe.

**Course description**

**Module 1: GT 08/M1 – Management Aspects**
Objective of reservoir management, management processes, integrated multidisciplinary team, database and tools, periodic monitoring of geothermal surface manifestation activities, chemical monitoring, reservoir performance

**Module 2: GT 08/M2 - Monitoring of Geothermal Activities**
Groundwater monitoring, subsidence and eruptive hydrothermal, monitoring of production well and hypodermic well, performance monitoring, Management of existing geothermal investments.

**Recommended Textbooks and journal for reading**

Course Unit Title: **GT 09: Geothermal Power Plant**

Contact Time: 6 Hours

**Course Unit Purpose**
This course unit is intended to empower a participant with technical knowledge in geothermal power generating systems that are currently in operation worldwide. The participant will also be able to appreciate the dynamics of generation of electrical energy from enthalpy water through energy conversion process.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Explain the working principles for typical components of standard geothermal power conversion systems,

b) Demonstrate an understanding of technical issues that are related to geothermal power generation with emphasis on controls that lead to optimal performance at different temperatures accompanied by high plant efficiency for flashed or binary systems.

**Course description**

**Module 1: GT 09/M1 - Components of Power Generation System**

Power house equipment, Automatic control and communication system: Cooling system, Particulate and/or droplet erosion, Heat exchangers, Gas evacuation systems, Re-injection system, Chemical injection system

**Module 2: GT 09/M2 - Power Generation Technical Concerns**

Standard geothermal power conversion systems: Flashed steam/dry steam condensing system, Flashed steam back pressure system, Binary or twin-fluid system, Power demand, Power plant Efficiency, Effect of resource temperature on the power generation density, operating practices and troubleshooting, Control systems, Hot Dry Rock, Enhanced Geothermal Systems, and Deep Hydrothermal Systems, hybrid conversion

**Recommended textbooks for Reading**

Course Unit Title: **GT 10: Geothermal Energy Utilization and Conversion**

**Contact Time:** 6 Hours

**Course Unit Purpose**
This course unit is intended to equip a participant with knowledge for understanding commercial aspects of energy utilization with emphasis on categorization of sectors that consume geothermal energy and conversion mechanisms undertaken at the power plant. The participant will also gain a positive attitude towards the positive development impact contributed by geothermal energy.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Describe different classification schemes of geothermal power plants considering different uses of geothermal power as a renewable energy,

b) Explain different uses of geothermal energy considering domestic, agricultural and industrial categories.

c) Explain processes for conversion of geothermal steam energy to electrical power,

**Course description**

**Module 1: GT 10/M1 - General aspects of utilization**
Introduction: Definitions; Power and energy, units of measurement, Forms of energy: geothermal energy, energy from fossil fuels, uses, comparison. Classification schemes: genetic, descriptive, types of geothermal power plants, direct use applications and geo-exchange systems.

**Module 2: GT 10/M2 – Consumers of geothermal energy**
Geothermal energy uses; direct uses of geothermal energy for drying agricultural product, aquaculture, green house, soil heating and others domestic use of geothermal steam industrial application, Energy conversion systems: gas extraction system.

**Module 3: GT 10/M3 – Geothermal energy conversion system**
Energy conversion systems; calculation of power output or steam consumption for power plant with dry steam cycle, separated steam cycle, single flash cycle.

**Recommended Textbooks and journal for reading**


Course Unit Title: **GT 11: Environmental Impact and Assessment**

Contact Time: 4 Hours

Course Unit Purpose
This course unit is intended to provide a participant with knowledge for understanding standard practices of assessing impact caused to the environment by geothermal activities. The participant will also be able to appreciate the importance of enforcing environmental protection measures that guarantees safety to health of geothermal workers.

Expected learning outcomes
At the end of this course unit the participant should be able to:

a) Explain the negative environmental impact caused by agents that are associated with geothermal resources,

b) Explain the generalize approach to environmental impact assessment considering restoration and rehabilitation technologies,

c) Describe environmental impact assessment measures put in place by established geothermal projects as well as mitigation enforcements.

Course description

**Module 1: GT 11/M1 - Environmental considerations**
Greenhouse emissions, land use, induced seismicity, groundwater contamination, subsidence, noise, and animal habitat issues.

**Module 2: GT 11/M2 - Environmental Impact**
Generalized approach to impact analysis, Guidelines for environmental auditing, Restoration and rehabilitation technologies, cost-benefit analysis, stakeholder management. Environmental impact measures for existing geothermal investments.

**Recommended Textbooks and journal for reading**


Course Unit Title: **GT 12: Geothermal Economics, Project Management and Funding of geothermal development**

**Contact Time:** 16 Hours

**Course Unit Purpose**
This course unit is intended to equip a participant with knowledge in economics that can enhance strategic project management skills thereby leading to more funding of ongoing geothermal investments. The participant will also be able to appreciate the importance of sound planning and financial controls that guarantee optimal performance of geothermal investments.

**Expected learning outcomes**
At the end of this course unit the participant should be able to:

a) Demonstrate an understanding of economic principles and practices that are applied to ensure viability of geothermal investments,
b) Explain contractual arrangements and planning activities that are essential for sound economic performance of geothermal power plants,
c) Carry out an economic analysis of a geothermal business venture considering risks that can emanate from poor cash flow due to fluctuations in electricity prices,
d) Explain the strategic management techniques that can be applied to ensure that geothermal projects remain vibrant as scheduled while utilizing available resources and addressing challenges that can arise having factored in operation project risks,
e) Demonstrate an understanding of integration of financial principles with best practice methodologies of costing that attracts financial support from investors and stakeholders while capturing typical examples from best performing geothermal investments on the globe,
f) Explain strategic management techniques that address stages of project operation while factoring in smart governance, team work and trust so as to achieve success as planned.
g) Demonstrate an understanding of procedures to be adopted for efficient handing over and closure of a geothermal investment having considered causes for project termination and the value of lessons learned from the management of the investment when it was vibrant,
h) Demonstrate an understanding of principles and practical issues that can commonly cause difficulties in commercial and financial negotiations for funding of geothermal projects in the competitive platform energy sector.

**Course description**

**Module 1:** **GT 12/M1- Nature and scope of economics**
Economic and non-monetary considerations, Organization in construction industry, Production: firm analysis, planning, input and output analysis.

**Module 2:** **GT 12/M2- Project Scope**
Contractual arrangement, regulations, planning of activities, cost for exploration, steam field development, power plant construction,

**Module 3:** **GT 12/M3- Project Analysis**
Risk analysis, time schedule, control, economic analysis, revenue analysis, calculation of electricity price, cash flow.

**Module 4: GT 12/M4- Project management Principles**
Fundamentals of project management, strategic management, planning, scheduling and resource management, risk management, typical challenges for geothermal project management,

**Module 5: GT 12/M5- Geothermal Project costing and financing**
Financial principles, techniques, and best-practice methodologies of scheduling and cost control, Worked out examples,

**Module 6: GT 12/M6- Planning and management of geothermal projects phases**
Initial stage, operation stage, business intelligence, project governance, teamwork, and trust.

**Module 7: GT 12/M7- Project handover, closeout and reviews**
Project objectives, and requirements, success, unmitigated disaster, lessons learned, hand over and closure process. Regardless of the outcome, projects should be closed effectively and efficiently to preclude any future problems and serve as a lesson to other projects in the future.

**Module 8: GT 12/M8- Project Funding**
Funding conceptualization, types of credit markets, legal constraints, contractual commitments, scheduling, sources of project finance; typical commercial, contracts, finance risk assessment.

**Recommended Textbooks and journals for reading**

Course Unit Title: GT 13  Field Excursion and Power Plant Visit

Contact Time: 30 Hours

Course Unit Purpose
This course unit is intended to offer a participant an opportunity of visit sites of geothermal activities and an active geothermal plant so as to confirm field realities. The participant will also be able to appreciate the significance of identifying sites of geothermal manifestations that becomes a precursor to further investigations.

Expected learning outcomes
At the end of this course unit, a participant should be able to:
a) Distinguish different geological sites that represent geothermal manifestations and identify associated geological features and allied elements of environmental concerns,
b) Identify components for the geothermal power plant visited,
c) Carry out selected measurements of operation parameters for an active geothermal plant,
d) Write and submit a technical report for the field excursions made.

Module 1: GT 13/F1 – Geothermal Sites
Hydrothermal minerals, geothermal manifestations, structures, indications of heat sources, rock types, recharge mechanism, tephra chronology, sequence and chronology of rock emplacement

Module 2: GT 13/F2 - Power Plant Visit
Power plant operation parameters, environmental issues, mitigation measures.

Module 3: GT 13/L1 - Report writing
Conceptual Model: Development of a geological model and interpretation of the models. Interpretation of field data, report writing.
# Appendix 1: Proposed Program Time Table

## WEEK 1

<table>
<thead>
<tr>
<th>TIME</th>
<th>SUNDAY</th>
<th>MONDAY</th>
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<th>WEDNESDAY</th>
<th>THURSDAY</th>
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<tbody>
<tr>
<td>8.am - 10.00 am</td>
<td>Opening Ceremony/ Program Overview</td>
<td>GT 01/M3 RP 1 ROOM _</td>
<td>GT 01/M5 RP 2 ROOM _</td>
<td>GT 02/M1 RP 2 ROOM _</td>
<td>GT 03/M1 RP 3 ROOM _</td>
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<td>2.00 pm - 4.00 pm</td>
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<td>GT 01/M4 RP 2 ROOM _</td>
<td>GT 01/M7 RP 1 ROOM _</td>
<td>GT 02/M2 RP 2 ROOM _</td>
<td>GT 03/M2 RP 3 ROOM _</td>
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<td>4.30 pm - 6.00 pm</td>
<td>Slide/Video Show</td>
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<td>GT 04/M2 RP 4 ROOM _</td>
<td>GT 05/M1 RP 5 ROOM _</td>
<td>GT 06/M1 RP 6 ROOM _</td>
<td>GT 07/M1 RP 7 ROOM _</td>
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<td>GT 09/M2 RP 9 ROOM _</td>
<td>GT 10/M3 RP 10 ROOM _</td>
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<td>GT 11/M1 RP 11 ROOM _</td>
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### TRAVELLING TO THE FIELD
- Geothermal Sites GT 13/F1 RP 13
- Power Plant Visit GT 13/F2 RP 13

### RETURNING TO THE CENTER
- Report Writing GT 13/L1 RP 13 ROOM _
- Report Submission

### KEY
- GT 01/M1 to GT 12/M8 -- Module Codes
- RP 1 to RP 13 -- Resource Persons

## WEEK 4

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<td>Report Submission</td>
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<td>4.30 pm - 6.00 pm</td>
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<td>Awards/Closing Function</td>
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### DEPARTURE
- TRAVELLING TO THE FIELD
- RETURNING TO THE CENTER

### KEY
- GT 01/M1 to GT 12/M8 -- Module Codes
- RP 1 to RP 13 -- Resource Persons