THE MEXICAN CENTER FOR INNOVATION IN GEOTHERMAL ENERGY (CeMIE-Geo): RESEARCH LINES AND SERVICES

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ABSTRACT

CeMIEGeo is an academic-industry alliance funded by the Secretary of Energy of the Mexican government (SENER) and the National Council of Science and Technology (CONACYT). It is comprised by 7 academic institutions, 1 public company, and 17 private companies. It is headed by the CICESE, the largest of the CONACYT centers, founded in 1973 and dedicated to scientific research and higher education. CeMIE-Geo's objectives are: to expand and strengthen the capability for scientific and technological research in geothermal energy, promoting collaborative use of infrastructure and expertise; to promote innovation and creation of technology-based companies, strengthening the technological development in the geothermal sector, and to foster education and training of specialists for academy and industry. The work of the CeMIE-Geo focuses on R&D lines including: exploration and resource assessment, technological development, direct uses of geothermal heat, specialized training and capability building, specialized laboratory analyses of fluids gases and rocks. Besides scientific research, our goal is to provide specialized services to geothermal industry. In this paper, a brief description of our capabilities is given, particularly on exploration geoscience, laboratory facilities and direct use demonstrative projects.

Keywords:CeMIEGeo, CeMIE-Geo, CICESE, Mexico, geothermal energy, innovation, research, development, projects.

1. INTRODUCTION

The law for the use of renewable energies and the financing of the energy transition (LAERFTE) establishes that by 2024 the participation of non-fossil sources in the generation of electricity should be 35%. For this, it is necessary to increase the participation of renewable technologies as a key factor for Energy Security and Environmental Sustainability. The use of renewable energies is a thematic area of interest for the Energy Sustainability Fund and one of the main research areas where the scientific-technological community of the country has focused its efforts for several years. Particularly, we have capacities in geothermal, solar, wind, bioenergy, and on a smaller scale, energy from the ocean. The potential of these capacities requires strengthening, consolidation and linking, a situation that will allow them to align, reinforce and improve their conditions.

The Mexican Centers Innovation in Energy (CEMIEs) are an initiative of the Ministry of Energy and the National Council of Science and Technology, through the Energy Sustainability Fund, aligned with these needs: The use of renewable energies, the consolidation and linking of existing scientific and technological capabilities in these issues, and the consequent training of specialized human resources and strengthening of infrastructure for research. The initiative of the Mexican Energy Innovation Centers is based on some of the best practices implemented in other countries and based on the premise of promoting an innovative model. The CEMIEs are the first stone in the change of paradigm on the research and the technological development of the electric sector. The CEMIEs are national, comprehensive and inclusive projects that involve the formation of consortiums where national existing capacities are combined and aligned. They involve higher education institutions, research centers, companies and others.

Among their main functions are the medium-term and long-term scientific-technological planning focused on developing each of the renewable technologies, the development of a portfolio of projects and strategic actions that allow obtaining valuable results for the energy sector of the country, the training of specialized human resources, the strengthening of the research infrastructure and the link between academia and industry. One of these centers is the the **Mexican Center for Innovation in Geothermal Energy** (CeMIE-Geo) of which a brief description of its capabilities is given, particularly on exploration geoscience, laboratory facilities and direct use demonstrative projects.

2. THE MEXICAN CENTER FOR INNOVATION IN GEOTHERMAL ENERGY (CeMIE-Geo)

The CeMIE-Geo is an academic-industry alliance funded by the Mexican Secretary of Energy (SENER) and the National Science and Technology Council (CONACYT) in Mexico. It consists of 7 academic institutions, 1 public company (CFE) and 17 private companies. It is led by CICESE, an institution funded by CONACYT in 1973, aimed for scientific research and higher education.

The general purposes of CeMIE-Geo are:

- To expand and strengthen the capability for scientific and technological research in geothermal energy, promoting collaborative use of infrastructure and expertise.
- To promote innovation and creation of technology-based companies, strengthening the technological development in the geothermal sector.
- To foster education and training of specialists for academy and industry.

PARTICIPANT INSTITUTIONS

Academy

- CICESE: Centro de Investigación Científica y Educación Superior de Ensenada, B.C.
- INEEL: Instituto Nacional de Electricidad y Energías Limpias
- UMSNH: Universidad Michoacana de San Nicolás de Hidalgo
- UNAM: Universidad Nacional Autónoma de México
- UPBC: Universidad Politécnica de Baja California
- UdeG: Universidad de Guadalajara
- CIATEQ: Centro de Tecnología Avanzada, A.C.

Industry

- Comisión Federal de Electricidad (public company)
- BajaInnova, SAPI de CV
- Cluster de Energías Geotérmica y Renovables, AC
- Especialistas en Turbopartes, SA de CV
- Exploración Perforación y Estudios del Subsuelo, SA de CV
- Geoconsul, SA de CV
- Geología Minería y Consultoría, SA de CV
- Generadores de Negocios en Energía Renovable y Ambientales, SC
- Geotem Ingeniería, SA de CV
- GS Energía, SA de CV
- Prados Camelinas, SA de CV

PROJECTS

- 30 strategic projects
- Promotion of specialized training programs
- Specialized Laboratory System

RESEARCH AND DEVELOPMENT LINES (INVOLVED INSTITUTIONS)

- Resource assessment (UNAM, INEEL, UMSNH)
- Exploration techniques (CICESE, UNAM, UMSNH, UdeG)
- Technological developments (UNAM, INEEL, UMSNH)
- Direct uses of geothermal heat (UPBC, INEEL, UMSNH)
- Specialized Laboratory System (UNAM, CICESE, UMSNH, INEEL)
- Training Programs (CICESE, UNAM, UMSNH, INEEL, UPBC, UdeG)

RESOURCE ASSESSMENT

Motivation: Collecting basic information about temperature, heat flow and geothermal gradient in the country.

Data acquisition campaigns and comprehensive studies of heat flow, geothermal provinces, as well as improved assessment of thermal manifestations and aquifers, to have an updated estimate of the country's geothermal potential, initially for conventional hydrothermal systems but also for unconventional resources as hot dry rock systems and other resources, including marine resources. There are 4 specific projects in this area:

- P01 Geothermal gradient and heat flow maps of Mexico. UNAM
- P02: Map of geothermal provinces in Mexico from fluid geochemistry and distribution of aquifers. UNAM
- P07: Assessment of the Enhanced Geothermal System (EGS) potential for power production in Mexico. INEEL
- P20: Assessing the potential and over-exploitation of the geothermal power capacity of Mexico using noble gas isotopes. UMSNH.

EXPLORATION TECHNIQUES

Motivation: We need to develop exploration technologies to reduce uncertainty in location of the resources as well as in estimation of size, temperature and chemical characteristics. The proposed projects propose experimenting with new geological, geophysical and geochemical techniques. There are 9 specific projects in this area:

- P03: Intensive survey of geothermal exploration in Wagner, Consag, Delfín, Guaymas and Alarcón basins in the Gulf of California rift system. CICESE
- P04: Spatial and temporal monitoring of geophysical variables in geothermal fields. CICESE
- P05: Integration of modern techniques for geothermal exploration using geological, geochemical and geophysical methods. UNAM
- P08: Development, implementation and application of analytical methodologies of water/rock interaction processes in geothermal reservoirs of low and high enthalpy: Application to Mexican fields. UNAM
- P09: Development and application of new advanced methods in fluid geochemistry and hydrothermal alteration for the exploration of geothermal systems. UNAM
- P15: Geothermal exploration of the volcanic complexes of Cerritos Colorados, Acoculco and El Aguajito-Reforma: Insights from volcanology, stratigraphy, geochemistry and experimental petrology. UNAM
- P17: Fracturing, faulting and current deformation field study, supported by seismic analysis and tomography in the geothermal fields of Cuitzeo, Mich., and Cerritos Colorados, Jal. UMSNH
- P23: Testing probes for measuring shallow heat flow in geothermal zones. UMSNH
- P24: Passive seismic and magneto-telluric exploration in the Tulancingo-Acoculco and Ceboruco Volcano geothermal fields. UdeG.

TECHNOLOGICAL DEVELOPMENT

Motivation: Although the technology associated with thermodynamic cycles and construction of equipment for power generation is well known, there is still some scope for innovations. In this category we want to promote Mexican geothermal engineering and motivate the creation of technology-based companies. There are 10 specific projects in this area:

- P06: Development of computer tool based on the best available equation of state, for the calculation of thermodynamic properties of H2O and CO2 mixtures in a wide range of pressure, temperature and composition. INEEL
- P14: GeoSteam.Net: A vapor transport simulator to optimize the design of steam-pipeline networks and generation of electrical energy in a geothermal field. INEEL
- P18: Monitoring the structural integrity of pipes by ultrasonic guided wave tomography. UMSNH
- P19: Development of super-alloys and special titanium-based alloys for applications in turbines for geothermal power generation. UMSNH
- P21: Geothermal power generation using CO2 captured from fossil-fired power plants. UMSNH
- P25: Sustainable development and minimization in the environmental impact of the geothermal reservoir's exploitation in Mexico. CICESE
- P29: Design and construction of a low enthalpy turbo-generator with capacity of 300 kW. UMSNH
- P31: Evaluation of technologies to maximize the extraction of geothermal energy deposits of medium and low enthalpy. UMSNH
- P32: Design of a comprehensive methodology for the perforation of geothermal sites of medium and low enthalpy, with technology innovation and definition of risk parameters. UMSNH
- P33: Development of a model for technical, financial, legal and regulatory feasibility assessment of high, medium and low enthalpy geothermal exploration and development projects. UMSNH.

DIRECT USES OF GEOTHERMAL HEAT

Motivation: Technologies for thermal conditioning of spaces and industrial applications of geothermal heat have been used for decades in other countries. However, these mature technologies are basically unknown by Mexican entrepreneurs and the general public. It is necessary to spread the technology by conducting technical and economic studies and by developing demonstration projects to show the feasibility of this type of applications. There are 7 specific projects in this area:

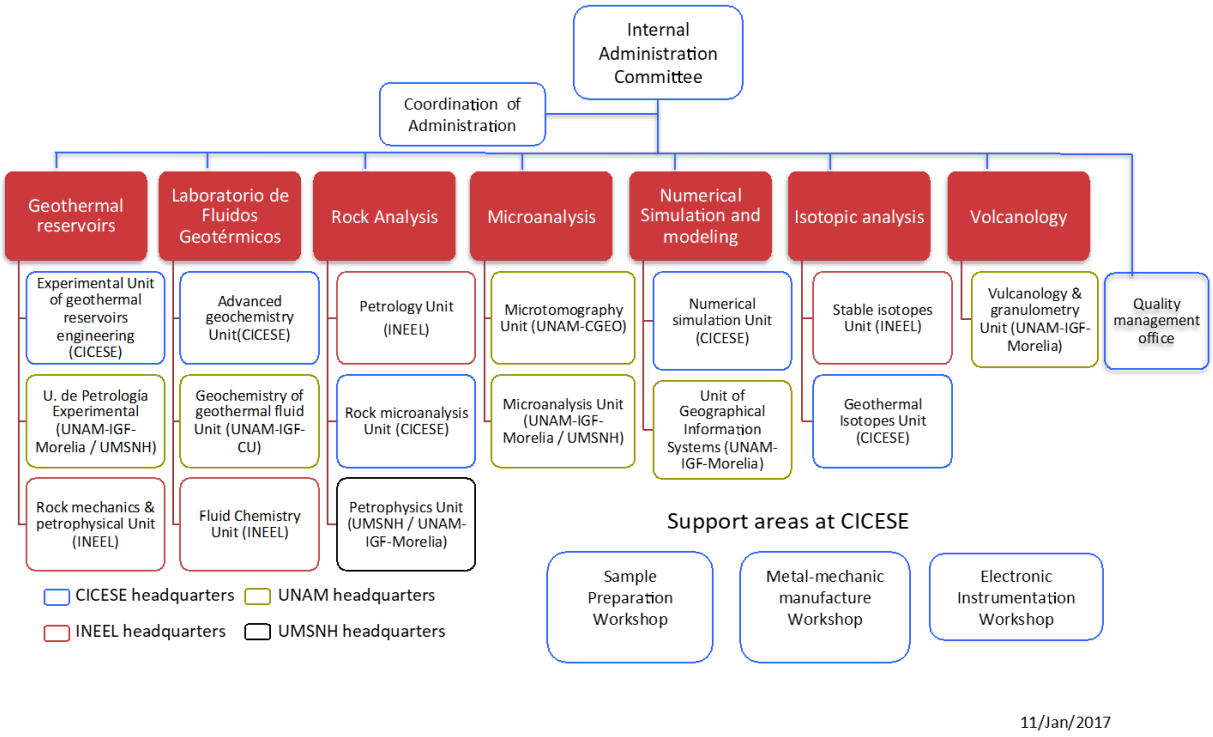
- P10: Feasibility analysis and development of a prototype demonstrating the use geothermal energy for heating of greenhouses. UPBC
- P11: Technological developments for the use of low enthalpy geothermal energy. UNAM
- P13: Feasibility analysis, comparison of technologies, market research, and development of a Geothermal Heat Pump (GHP) demonstration project for air conditioning of residential and

commercial spaces in Mexicali, Baja California and Cuernavaca, Morelos, Mexico. INEEL

- P16: Integration of a poly-generation plant using geothermal energy through a cascade concept. UMSNH
- P22: Modular design system for residential air conditioning through the use of geothermal energy. UMSNH
- P27: Design, development and detailed characterization of a food drying geothermal heat system with the quality required by the food industry. UMSNH
- P30: Development of a system for the generation of controlled-climate from the exchange of heat with the subsoil and the utilization of the thermal inertia of the earth's crust, with applications to industrial, commercial, public and household spaces. UMSNH.

SPEZIALISED LABORATORY SYSTEM

Motivation: A key component of CeMIE-Geo is a Specialized Laboratory System comprising seven laboratories located throughout Mexico in four institutions: UNAM, UMSNH, CICESE and INEEL. The goal is to have world-class facilities providing analytical capacity for our projects and offer analytical services to all the geothermal industry.



Organization chart of the Spezialised Lab System

Main Equipment

- Computational cluster with 1536 cores and 3072 GB of memory
- HP-HT material characterization equipment
- Rock Compressibility System (RCS 700)
- ICP-MS instruments
- Hydride Generator coupled to a microwave plasma and atomic emission spectrometry (HG- MP-AES)
- Ion-chromatograph DIONEX 2100
- High pressure liquid chromatography (HPLC)
- Gas chromatography coupled to mass spectrometry (GC/MS)
- Noble Gas Mass-Spectrometer
- Optical Emission Spectrometer Inductively Coupled Plasma (ICP-OES)
- X-Ray Fluorescence Spectrometer
- X-ray system of micro-computed tomography
- EPMA electron microscope
- Infrared Spectrometer FTIR

TRAINING PROGRAMS

Motivation: The capability of the Mexican geothermal industry is due to the existence of well-trained personnel in all the phases of the geothermal projects, both in CFE as well as in other institutions. However, there is an urgent need to train new technicians, engineers and scientists, through the creation of new geothermal training programs at all levels. Education programs offered by some of the academic institutions in CeMIE-Geo have national and international recognition. We will use these capabilities and our academic infrastructure to enhance and create new programs for training human resources at various levels:

- Short technical training courses
- Technical specialization programs (diploma) (UMSNH, INEEL, UNAM)
- Graduate programs (Dr. and M.Sc.) offered by UNAM, CICESE, UMSNH, UPBC and UdeG.

CONCLUSIONS

CeMIE-Geo is an alliance academic-industry funded by the Mexican Federal Government through the Secretary of Energy and the National Science and Technology Council. It consists of 7 academic institutions, 1 public company and 17 private companies. It is led by CICESE, an institution aimed for scientific research. The purposes of CeMIE-Geo are: to expand and strengthen the capability for scientific and technological research in geothermal energy, promoting collaborative use of infrastructure and expertise; to promote innovation and creation of technology-based companies, strengthening the technological development in the geothermal sector, and to foster education and training of specialists for academy and industry.

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