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Centre for Geothermal Energy Research (CGER) at CSIR–NGRI, Hyderabad: Advancing sustainable geothermal energy in India

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INTRODUCTION

The CSIR–National Geophysical Research Institute (CSIR–NGRI), Hyderabad (India), is country's unique geoscientific research institution, dedicated to research investigations spanning from near-surface processes to deep Earth exploration with a strategic focus on natural resource exploration (groundwater, mineral, geothermal energy, and hydrocarbon) and hazard assessment for sustainable development. Among various renewable energy resources, geothermal energy stands out as a reliable, clean, and sustainable resource, capable of providing continuous baseload power, independent of climatic or seasonal variability (Gupta and Roy, 2007). Leveraging its multidisciplinary expertise in geological, geochemical, and geophysical sciences, CSIR–NGRI, the Geological Survey of India (GSI) and other institutions, have led national efforts that have resulted in the delineation of ten geothermal provinces across the country's diverse tectonic settings (Figure 1). Although India possesses considerable geothermal potential, particularly in regions with hot springs, this resource remains largely untapped.

CSIR–NGRI has a long-standing legacy in geothermal research, spanning over six decades, with pioneering contributions in heat flow measurements, subsurface temperature mapping, characterization of rock thermal properties, geophysical imaging, and geochemical analyses across various geological terrains in India (Saxena and Gupta, 1986; Patro, 2017; Ray, 2021).

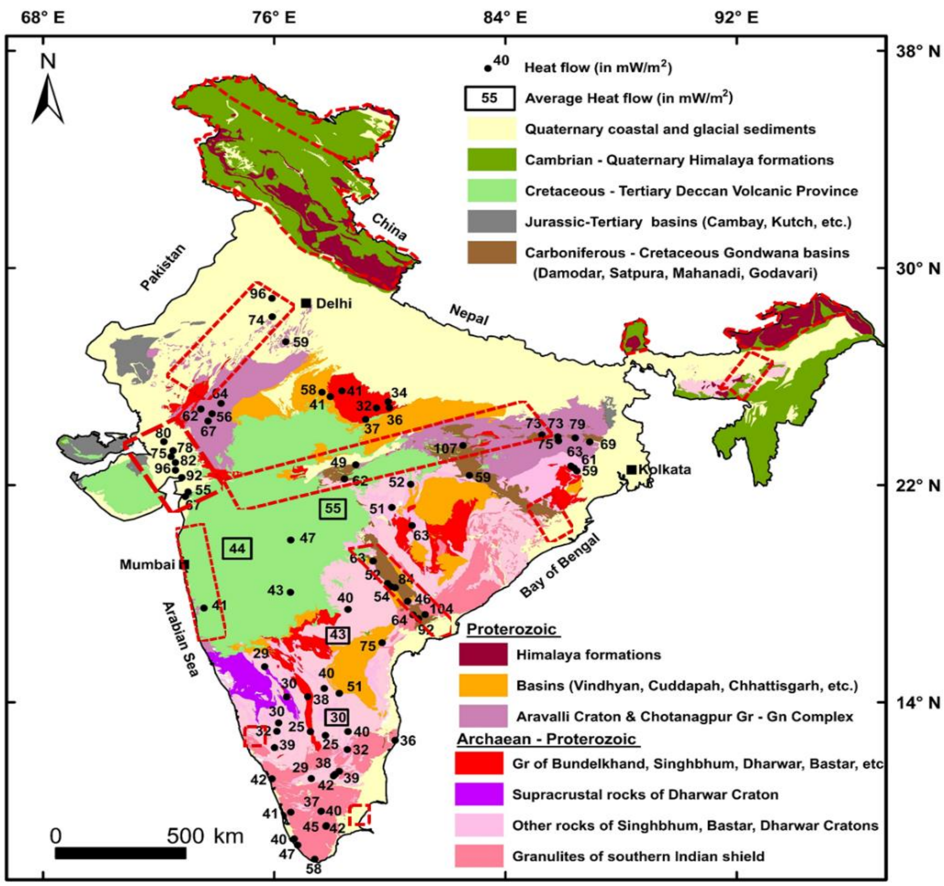

Figure 1. Geological map of India showing geothermal provinces (modified after GSI, 2022) along with heat flow distribution.

These sustained multidisciplinary efforts have provided the scientific foundation for delineating the geothermal reservoirs and advancing site-specific resource assessment in key geothermal provinces. Among the ten identified potential geothermal provinces, this institute is currently leading major integrated investigations in two key geothermal provinces, viz. Puga–Chumathang–Panamik region of the Ladakh Himalaya (Pavankumar et al., 2024; Dutta et al., 2025; Kumar et al. 2025a; Ojha et al., 2025; Patro et al., 2025) and the Tattapani geothermal province in Chhattisgarh (Kumar et al., 2025b; Maurya et al., 2025; Ray et al., 2025a, b, c). These initiatives represent a strategic step towards harnessing indigenous clean energy resources to enhance national energy security and economic development. Furthermore, sustained scientific deliberations through national conclaves (Ray et al., 2023), expert brainstorming, and comprehensive field studies culminated in the establishment of the Centre for Geothermal Energy Research at CSIR–NGRI. This dedicated centre provides a focused institutional framework for advancing geothermal science, developing indigenous technologies, and supporting sustainable geothermal exploitation, in alignment with India's National Policy on Geothermal Energy (Ministry of New and Renewable Energy, MNRE; 2025) and the country's commitment to achieving net-zero emissions by 2070.

CENTRE FOR GEOTHERMAL ENERGY RESEARCH (CGER)

The Centre for Geothermal Energy Research (CGER) was inaugurated on September 9, 2025, by Dr. (Mrs.) N. Kalaiselvi, Director General, CSIR & Secretary, DSIR, Government of India, at CSIR–NGRI, Hyderabad. The event was attended by directors of CSIR sister laboratories, scientists, and staff of CSIR–NGRI (Figure 2). CGER envisions becoming a leading Centre of Excellence in geothermal research by integrating advanced geological, geochemical and geophysical approaches to explore, understand, and harness geothermal energy in a sustainable manner. Its mission is to advance geothermal exploration through integrated geoscientific research (Ray et al., 2025d), foster the development of innovative subsurface technologies, and establish a national geothermal data repository, while nurturing future energy professionals and fostering impactful national and global collaborations.

The CGER will serve as a national hub for geothermal research and development, focusing on subsurface imaging, fluid characterization, and the development of a comprehensive data repository. It fosters national and international collaborations to advance geothermal science and technology. The centre also emphasizes training the next generation of geothermal professionals to build capacity in this emerging sector (Figure 3). Together, these efforts guide CGER's mission to enable sustainable geothermal energy exploration and utilization of geothermal resources in India.

CGER aims to contribute to the United Nations Sustainable Development Goals, including affordable and clean energy (SDG 7), industry, innovation, and infrastructure (SDG 9), sustainable cities and communities (SDG 11), and climate action (SDG 13) (United Nations, 2015). In parallel, the centre advances research in support of India's national missions, Atmanirbhar Bharat and Viksit Bharat 2047. Its vision is fully aligned with India's National Policy on Geothermal Energy (MNRE, 2025) and the country's long-term commitment to achieve net-zero emissions by 2070.

Figure 2. Inauguration of CGER by Dr. N. Kalaiselvi, DG, CSIR, and Secretary, DSIR.

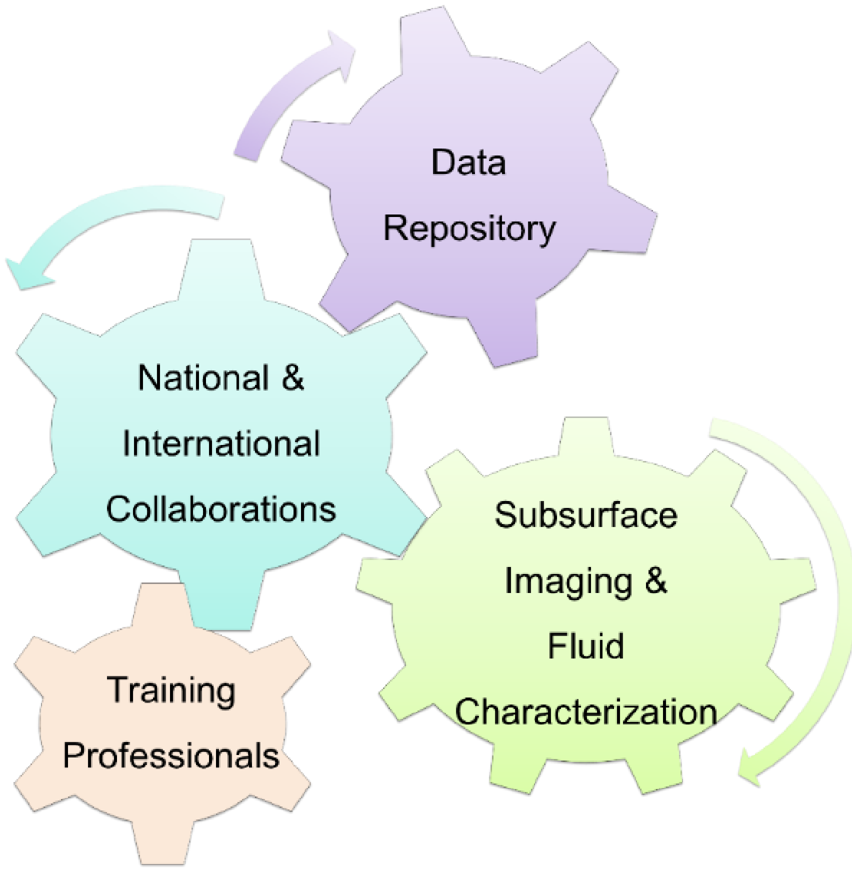

Figure 3. Roles and responsibilities of CGER.

FACILITIES AT CGER

The CGER hosts an integrated facility encompassing geophysical, thermal, rock mechanics, and hydrogeochemical capabilities, forming a comprehensive scientific infrastructure for advancing geothermal research in India. These facilities enable systematic investigation of subsurface heat and fluid flow, reservoir properties, and coupled thermo-hydro-mechanical processes, which are critical for understanding and sustainable development of geothermal systems. Geophysical facilities offer capabilities to characterize subsurface structures and physical properties through the seismic, electrical, electromagnetic, gravity, and magnetic investigations. These tools are crucial for imaging fault systems, mineralized zones, as well as delineating the depth and dimension of the geothermal reservoirs. Mapping of fracture zones and their interconnectivity is mainly done by various electrical methods such as Electrical Resistivity Tomography (ERT) and Electric-field Vector Resistivity Imaging (EVRI), shallow seismic, gravity and magnetic, whereas, deep geothermal reservoirs are investigated by magnetotellurics (MT), seismic and gravity methods (Figure 4).

Thermal facilities are used to determine geothermal gradient, radiogenic heat production, thermophysical properties of rocks and its variation with temperature. These datasets are used to determine surface heat flow, thermal regime of the geothermal provinces (Figure 5).

Rock mechanics facilities focus on the mechanical behaviour of rocks and geomaterials under controlled stress, temperature, and pore pressure conditions. They support experimental studies on rock strength, deformation, fracture propagation, and thermo-hydro-mechanical (THM) coupling, which are vital for understanding reservoir stability, induced seismicity, underground excavations, and subsurface energy storage (Figure 6).

Hydrogeochemical facilities enable detailed analysis of groundwater and geothermal fluids, including major ions, trace elements, isotopes, and gas chemistry. These analyses provide critical insights into fluid origin, evolution, water–rock interaction processes, and geochemical controls on resource sustainability and environmental quality (Figure 7).

Figure 4. Geophysical field instrumentation set-ups for subsurface investigations in geothermal exploration **(a)** Electrical Resistivity Tomography (ERT), **(b)** Electric-field Vector Resistivity Imaging (EVRI), **(c)** Magnetotellurics (MT), **(d)** Seismic, **(e)** Gravimeter, and **(f)** Magnetometer.

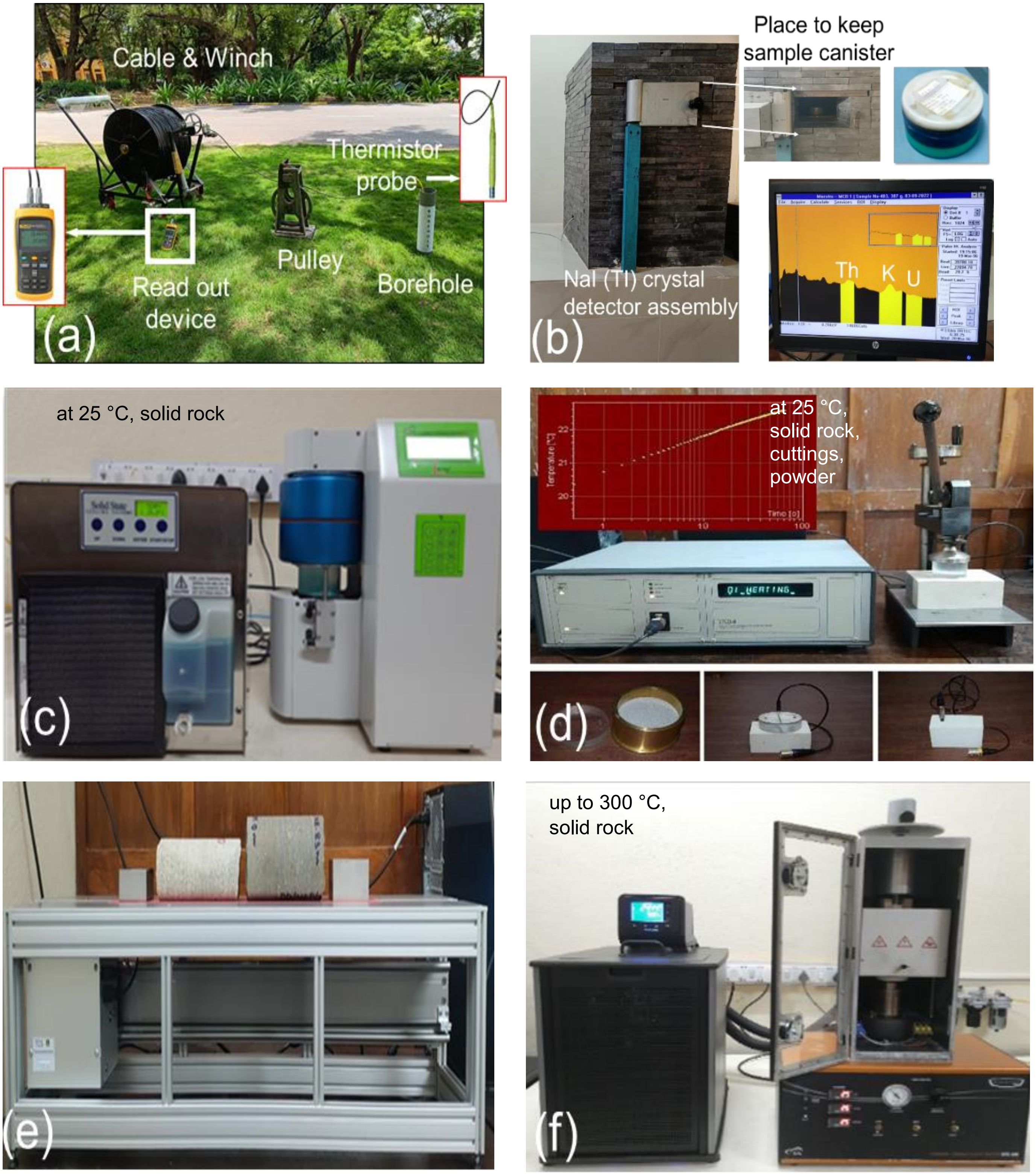

Figure 5. Field and laboratory facilities for thermal investigations in geothermal exploration. **(a)** Borehole temperature logging set-up, **(b)** Rock radioactivity measurement set-up, **(c)** Steady-state thermal conductivity meter, **(d)** Transient thermal conductivity meter, **(e)** Thermal conductivity scanner, **(f)** Steady-state thermal conductivity meter at elevated temperature.

Figure 6. Laboratory facilities for rock mechanical and physical properties. **(a)** Universal Testing Machine, **(b)** Triaxial Testing Machine, **(c)** Gas Pycnometer, **(d)** Density and porosity measurement set-up.

Figure 7. Laboratory facilities for hydrogeochemical investigations for geothermal exploration. **(a)** Ion Chromatography with Autosampler for Major anions and cations, **(b)** High Resolution-Inductively Coupled Plasma Mass Spectrometer (HR-ICP-MS) for Trace Elements and REEs, **(c)** Isotope Ratio Mass Spectrometer (IRMS) for Stable isotopes, **(d)** Gas Chromatograph-Mass Spectrometer (GC-MS) for gases.

FUTURE DIRECTIONS AND WAY FORWARD

CGER has outlined its strategic road map for advancing geothermal research and development in India, with a focus on translational outcomes, national priorities, and long-term sustainability, through the following thematic areas.

Advanced geothermal resource assessment and characterization

CGER will enhance integrated geothermal exploration through high-resolution geophysical imaging, heat flow mapping, thermophysical property measurements, and geochemical/isotopic studies. Emphasis will be placed on identifying reservoir depth, geometry, permeability, and sustainable heat extraction potential in both conventional and unconventional geothermal systems across India.

Development of enhanced and low-enthalpy geothermal systems

Future research will focus on Enhanced Geothermal Systems (EGS), as well as medium- to low-enthalpy resources and direct-use applications. Numerical modeling of thermal–hydraulic–mechanical (THM) processes will support feasibility assessments and reservoir sustainability.

Feasibility demonstration and technology translation

CGER will work towards pilot-scale geothermal demonstration projects in collaboration with MNRE, PSUs, state agencies, and industry partners. This will serve to validate technology, reduce risk, and facilitate the transition from exploration to utilization, thereby bridging the gap between research and applications.

Geothermal integration with energy systems and net-zero goals

It involves integrating geothermal energy with hybrid renewable systems (solar–geothermal, geothermal heat pumps) and district heating/cooling networks. CGER will contribute to de-carbonization strategies aligned with India's net-zero emissions target for 2070 by promoting geothermal as a reliable, base-load, and climate-resilient energy source.

Digital geothermal atlas and national data repository

The CGER aims to develop a dynamic, GIS-based geothermal database that integrates geological, geophysical, geochemical, and thermal datasets. This digital platform will support national planning, investor confidence, and evidence-based policymaking under India's National Policy on Geothermal Energy.

Capacity building, skill development and knowledge dissemination

The Centre will strengthen human resource development through specialized training programs, doctoral and postdoctoral research, and international exchange initiatives. Outreach to state governments, academia, and industry will enhance awareness and promote informed decision-making for the development of geothermal energy.

International collaboration and policy support

CGER will expand strategic collaborations with leading global institutions to adopt best practices, advanced modelling tools, and innovative technologies. Scientific outputs will directly support national geothermal roadmaps, regulatory frameworks, and long-term energy planning.

CONCLUDING REMARKS

The establishment of the Centre for Geothermal Energy Research (CGER) at CSIR–NGRI, represents a significant step toward creating a unified national platform for advancing geothermal science, technology, and policy support in India. By integrating geological, geophysical, geochemical, and thermal studies, CGER addresses critical knowledge gaps related to resource characterization, reservoir sustainability, and utilization pathways across the country's diverse geothermal provinces. This multidisciplinary framework enables a scientifically robust assessment of geothermal potential, supporting the transition from exploration-driven studies to application-oriented outcomes. CGER's strategic focus on medium-to-low enthalpy systems, enhanced geothermal concepts, direct-use applications, and pilot-scale demonstrations, will position geothermal energy as a reliable, indigenous, and environmentally sustainable component of India's energy portfolio. The Centre's efforts contribute directly to national priorities, including energy security, de-carbonization, and regional development, while supporting India's commitments under the National Policy on Geothermal Energy and the net-zero emissions target for 2070. Through capacity building, digital data integration, and strong national and international collaborations, CGER strengthens India's technical and human resource base for long-term geothermal development. It is also aligned with the United Nations Sustainable Development Goals and national missions such as "Atmanirbhar Bharat" and "Viksit Bharat 2047", CGER exemplifies the role of science-driven institutions in enabling sustainable growth. Overall, the centre is poised to play a transformative role in translating India's geothermal potential into tangible benefits for society, the economy, and the environment.

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