



Chapter 4

Geothermal Cooling Opportunities

*Dr. Pradeepkumar Ashok, The University of Texas at Austin
Professor Shaija Andavan, NIT Calicut Kerala*

Geothermal cooling from ground source heat pumps and sedimentary aquifers is a powerful low-carbon option that can help meet India's growing and urgent cooling needs. The nation has an estimated 610 gigawatts of aquifer cooling potential in areas with high heat risk—and more than 1,500 gigawatts of total potential for aquifer cooling across the country.

As the most populous country in the world, India is at the forefront of a changing climate. In recent years, the nation has seen an increase in the frequency, intensity, and duration of extreme heat events, with daytime temperatures exceeding 45°C for extended periods of time in certain parts of the country.¹ This escalation in heat—compounded by urbanisation, humidity, and prolonged warm nights—is not only a climate hazard but also a multidimensional problem that affects human health and productivity, water availability, agriculture, and energy infrastructure.

According to the Council on Energy, Environment and Water (CEEW), more than one billion people across 57% of India's districts live in zones with high to very high heat risk.² The health risks of such heat can be severe if people

do not have access to cooling, though space conditioning has been shown to significantly enhance health, quality of life, and productivity. This growing heat burden threatens to reduce India's gross domestic product (GDP) by more than 5% by 2030—and in absolute terms is expected to cause the loss of the equivalent of 34 million full-time jobs.³

Using traditional air-conditioning to meet this challenge would require an enormous amount of energy, roughly 40% more than India currently produces.⁴ This level of energy use would, in turn, produce an additional 810 million tonnes of carbon dioxide equivalent (CO₂e) emissions annually by 2037.⁵ To put it another way, the projected energy increase for cooling alone in India would be in the top 10 of global CO₂ emissions unless the country takes action to use more efficient cooling approaches.



BY THE NUMBERS

- **323 million** people in India are at high risk due to heat.⁶
- Only **7%** of households in India have access to air conditioners.⁷
- **2024** was recognised as the hottest year globally since records were first kept.⁸
- Many states in India faced daytime temperatures above 40°C for an entire month in 2024, leading to more than **44,000** cases of heatstroke.⁹

These alarming figures underscore the need for a solution. By leveraging the thermal stability of the Earth’s subsurface in India, geothermal can provide powerful and efficient cooling to buildings via ground source heat pumps (GSHPs) and district cooling networks. (See “GSHP and District Cooling Network Installation in India” in this chapter and Chapter 1, “Geothermal 101:

Overview of Geothermal Technologies and Applications.”) Both solutions offer a renewable and round-the-clock alternative that reduces electricity use and peak load on the grid. Geothermal district cooling is especially suited to India’s sediment-rich basins, where high-permeability aquifers are often found in the subsurface of densely populated urban zones under acute heat stress.

In 2019, to address the sustainability of the nation’s growing need for cooling, the Ministry of Environment, Forest and Climate Change launched the India Cooling Action Plan (ICAP), a national campaign to reduce cooling demand by between 20% and 25% by 2038.¹⁰ ICAP does not directly address ground source heat pumps or geothermal cooling, but it does note the importance of district cooling and the increased use of efficient cooling options. More recently, India launched the 2025 National Policy on Geothermal Energy, which authorises the Ministry of New and Renewable Energy (MNRE) to support direct-use cooling applications through pilot projects and other policy mechanisms.¹¹

HEAT RISK ACROSS INDIA

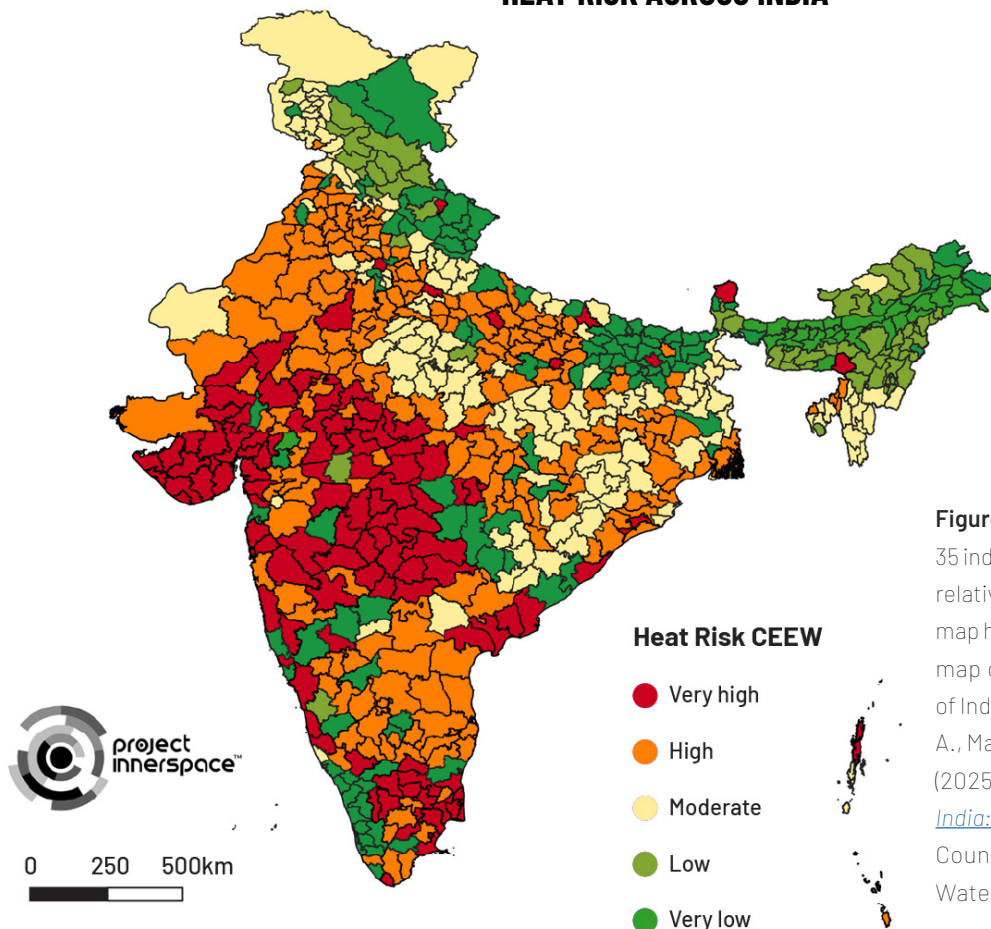


Figure 4.1: The data for this map include 35 indicators, including nighttime heat, relative humidity, and vulnerability. The map has been modified from the CEEW map of heat risk across 734 districts of India. Source: Prabhu, S., Suresh, K. A., Mandal, S., Sharma, D., & Chitale, V. (2025). [How extreme heat is impacting India: Assessing district-level heat risk](#). Council on Energy, Environment and Water (CEEW).

However, given the staggering impacts of rising temperatures and the unsustainability of traditional air-conditioning, geothermal should be part of the Indian cooling solution going forward, either through district cooling or ground source heat pumps (GSHPs). The country has more than 1,500 gigawatts of potential geothermal cooling capacity—and much more when including GSHPs. Gujarat, Gandhinagar, Anand, Mahesana, and Kheda offer the most promise for district cooling solutions. Chapter 8, “Policy and Regulatory Pathways to Catalyse Geothermal in India,” notes how important it can be for India to develop a national geothermal cooling mission that can launch these more efficient (and potentially lifesaving) technologies—and take advantage of this significant untapped cooling potential.

ELECTRICITY DEMAND FOR COOLING

As the world’s seventh-largest country by land area, India encompasses a wide range of climatic zones. Most of its citizens live in hot climates. The National Building Code of India recognises five zones for heating, ventilation, and air-conditioning (HVAC) and building design.¹² (See **Figure 4.7**.) One study covering 60 cities across India found that there were 171,974 total cooling degree days, compared with only 6,088 heating degree days.¹³ Another study analysed data from 14,500 weather stations across 219 countries and ranked India as first worldwide in total cooling degree days exposure (a product of the population and annual cooling degree days).¹⁴

For many years, air-conditioning was mostly confined to hospitals, cinemas, commercial spaces, and high-end residences. As of 2017, only 8% of India’s households had air-conditioning units, which amounted to about 40 million homes.¹⁵ That figure is now projected to grow threefold, to 170 million by 2027 (**Figure 4.2**).^{16,17,18}

Currently, the most common types of air-conditioning are fans, air coolers, room air-conditioning, packaged direct expansion systems, variable refrigerant flow systems, and chillers. Fans are widely used because they are simple and inexpensive and generally have low power requirements. Commercial buildings and large luxury residences primarily use large systems such as packaged direct expansion systems, variable refrigerant flow systems, and chillers.

PROJECTED GROWTH DEMAND FOR SPACE CONDITIONING SOLUTIONS

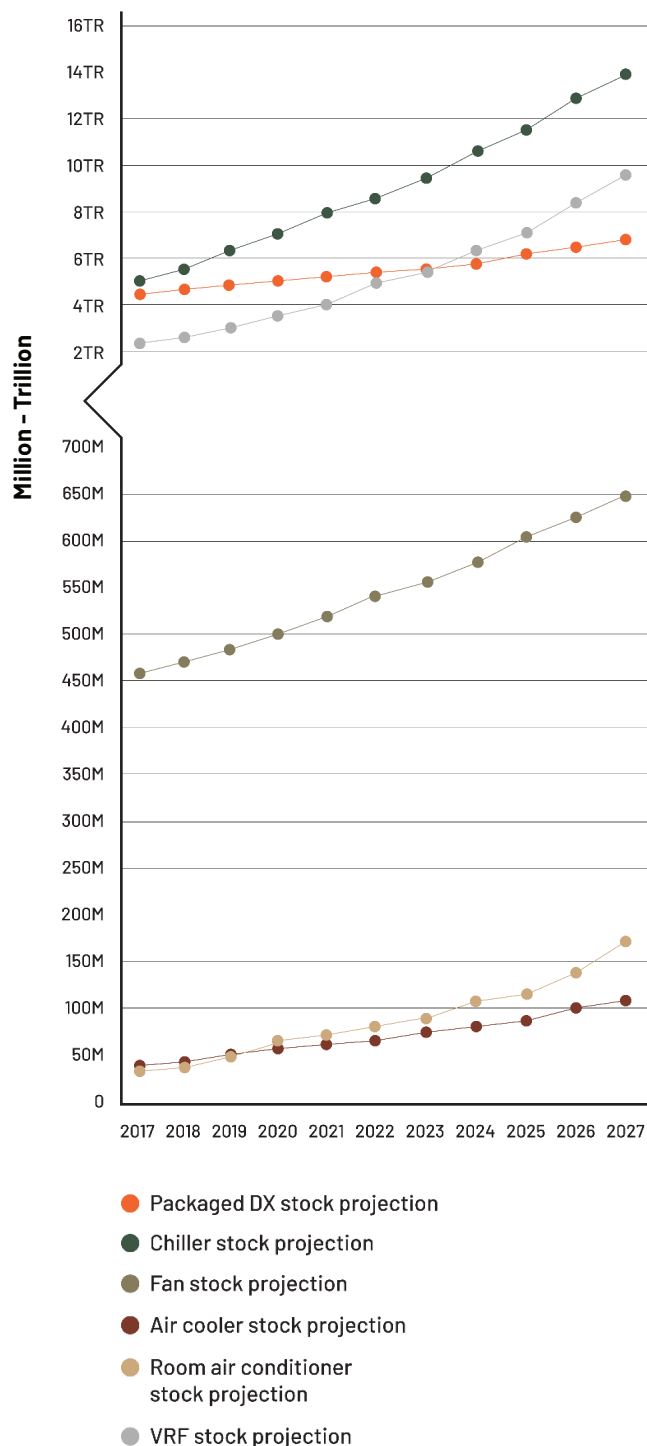


Figure 4.2: Projected growth in the demand for various space conditioning solutions in India. DX = packaged direct expansion system; TR=tonnes of refrigeration; VRF = variant refrigerant flow system. Source: Kumar, S., Sachar, S., Kachhawa, S., Goenka, A., Kasamsetty, S., & George, G. (2018). *Demand analysis of cooling by sector in India in 2027*. Alliance for an Energy Efficient Economy.



The total electricity generation in India for 2023–24 was about 1,734 terawatt-hours.¹⁹ Out of this amount, close to 200 terawatt-hours—or around 10% of the total—are estimated to have been used for space cooling needs.²⁰

In 2024, approximately 73% of the fuel used for electricity power generation in India was coal-based (Figure 4.3). In other words, a meaningful amount of India’s total air pollution and climate emissions stems from demand for cooling.

Out of this amount, close to 200 terawatt-hours—or around 10% of the total—are estimated to have been used for space cooling needs.

This growing demand is already placing enormous strain on India’s power grid—and the situation will only get worse. Even if it were possible to install traditional HVAC across the country, the energy and emissions costs would be enormous, requiring 180 gigawatts of additional power²¹ and generating an additional 810 million tonnes of CO₂e emissions annually by 2037,²² which would put India’s energy demand for cooling alone in the top 10 causes of CO₂ emissions globally.²³ This level of demand underscores the urgent need for sustainable cooling solutions that can operate at scale without exacerbating emissions.

ELECTRICITY GENERATION BY SOURCES, 2024–2025

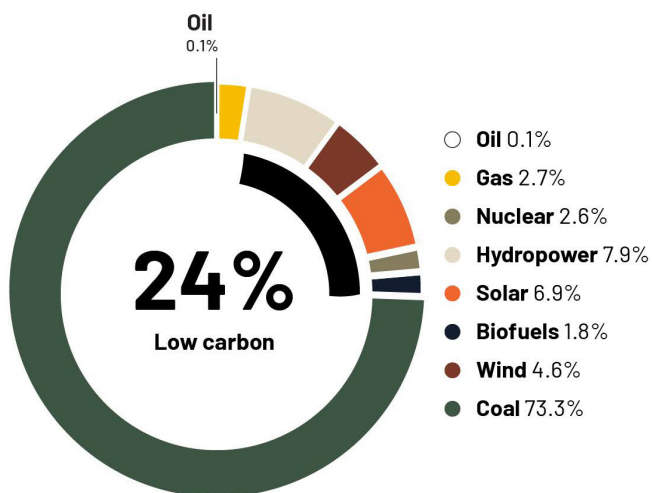


Figure 4.3: Electricity generation by source in India from September 2024 to August 2025. Source: Low Carbon Power. (n.d.). [Electricity in India in 2024/2025](#).

Even though India has the fifth-largest coal reserve in the world, it still has to import coal to meet its power generation requirements.²⁴ Adopting district cooling systems and GSHPs across the nation can help India meet its rising energy demands with a clean, homegrown energy source that reduces dependence on fossil fuels.

CO₂ EMISSIONS FROM COOLING TECHNOLOGIES

Type of System	2017		2037 (Projected)	
	Energy Consumption (TWh)	CO ₂ Emissions (million tonnes)	Energy Consumption (TWh)	CO ₂ Emissions (million tonnes)
Room air conditioner	56.7	40.4	304.2	216.9
Chiller system	12.2	8.7	64.4	45.9
Variable refrigerant flow system	4.1	2.9	52.7	37.5
Packaged direct expansion system	10.8	7.7	23.4	16.7
Fan	40.5	28.9	64.4	45.9
Air cooler	10.8	7.7	76.1	54.2
Total	135.0	96.3	585.0	417.1

Figure 4.4: Projected carbon dioxide (CO₂) emissions from cooling technologies between 2017 and 2037. TWh = terawatt-hours. Source: Adapted from data in Ozone Cell, Ministry of Environment, Forest and Climate Change. (2019). [India Cooling Action Plan](#). Government of India; combined with data from Our World in Data. (2025). [Carbon intensity of electricity generation, 2000 to 2024](#).



EQUITABLE OPTIONS: GSHPs AND DISTRICT COOLING

In many parts of India, access to cooling technologies remains deeply inequitable. Air-conditioning is still scarce outside of urban high-income areas, but India's rising income levels are accelerating the adoption of air-conditioning well beyond the wealthy elite.

Although electric fans are still the primary space-conditioning tool for much of the country, more Indians are adding room air conditioners to their homes as they become more affordable. The share of space cooling in India's peak electricity load is projected to rise from around 10% in 2018 to nearly 45% by 2050.²⁵

Meeting this rapidly growing demand affordably and sustainably is complicated. While solar power will account for roughly one-third of cooling-related generation additions,²⁶ solar's daily generation pattern does not

always align with evening cooling needs, forcing the grid to maintain costly peak capacity. GSHP technology—with or without deeper district cooling—is emerging as a promising solution.

GSHPs are particularly useful for urban environments, institutional campuses, and army bases. These systems harness the Earth's relatively stable shallow subsurface temperature so they can serve as a heat sink for cooling via electrically driven heat pumps. Because GSHPs use these stable temperatures, they can be twice as efficient as air source heat pumps and can be up to 70% more efficient than traditional HVAC solutions.²⁷ They can also deliver between three and five units of cooling per unit of electricity.²⁸ The more extreme the outside air temperature is, the more efficient GSHPs are, making them particularly well suited for India's climate.²⁹ Additionally, by using electricity only for compression, GSHPs significantly reduce cooling-related electricity demand and emissions compared with traditional HVAC

GEOTHERMAL HEATING AND COOLING FOR RESIDENTIAL BUILDING

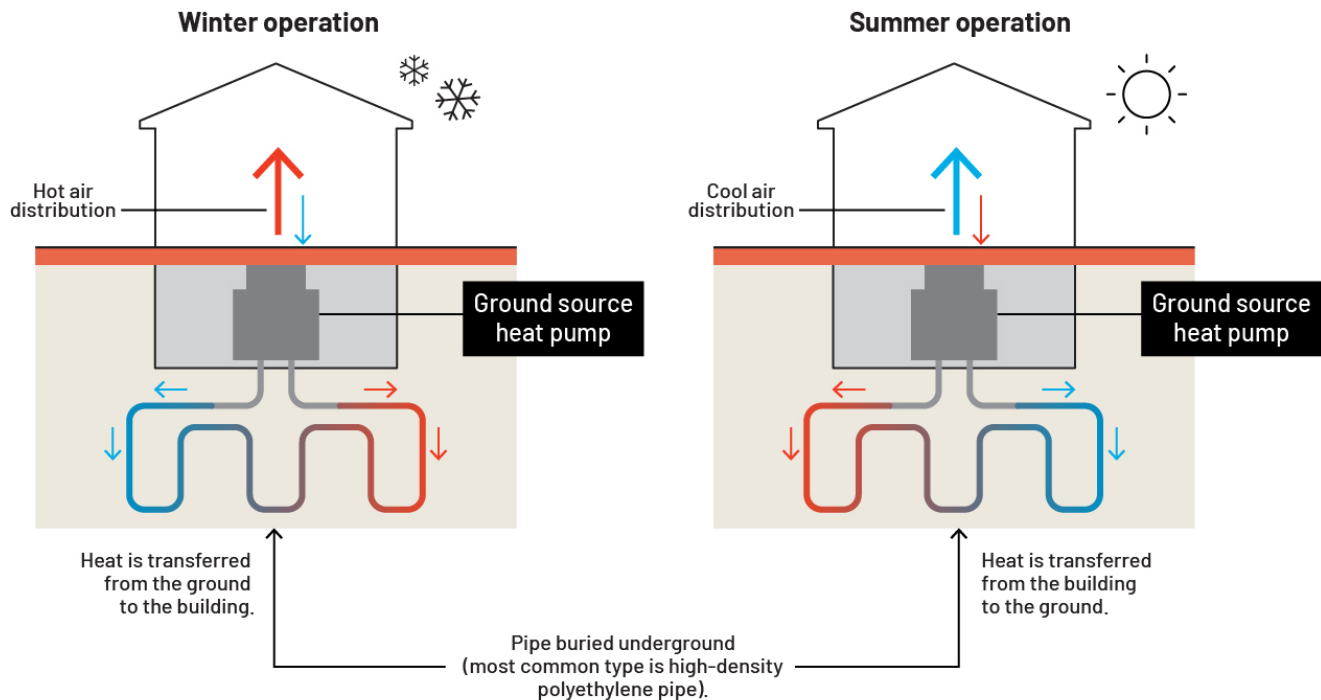


Figure 4.5: Geothermal heating and cooling for residential buildings. Source: Adapted from Lund, J. W. (2025). *Geothermal energy*. Encyclopedia Britannica.



systems. The electricity used by these systems can come from the grid, or the systems can be set up to run on solar and storage, ensuring the cooling system remains operational even if the grid is stressed.

The Indian Army's Net Zero Energy Building in Jhansi, commissioned in 2025, provides a compelling demonstration of GSHP technology. The facility uses 10 vertical boreholes that are 120 metres deep and connected to a closed-loop GSHP system, maintaining indoor temperatures at 22°C when outdoor extremes reach 43°C. Supported by rooftop solar photovoltaics, the building functions as an off-grid geothermal-cooled system and serves as a replicable model for cantonment and institutional infrastructure across India.³⁰

GSHP systems are broadly configured as follows:

- **Open-loop groundwater systems:** These systems extract and reinject aquifer water via heat exchangers and are viable where groundwater and regulatory clearances permit.
- **Horizontal closed-loop systems:** These systems involve shallow pipe loops buried between 1.5 metres and 2 metres underground and are effective for low-density developments with land availability.
- **Vertical closed-loop systems or borehole heat exchangers:** These systems drill to depths of between 60 metres and 150 metres and are ideal for buildings in densely populated areas due to their small surface footprint and high efficiency.

ADDED BENEFITS: DISTRICT COOLING NETWORKS

GSHP systems are highly compatible with next-generation district cooling networks (DCNs), which make it possible to distribute cooling power across multiple buildings.

In fourth-generation DCNs, a centralised energy station integrates GSHP arrays with either open-loop aquifer doublets or buried closed-loop collectors. Cooled water is distributed via insulated pipes to selected buildings, which extract cooling using heat interface units. This setup is suitable for smart city districts, government estates, and commercial precincts with coordinated infrastructure (see **Figure 4.6**).³⁵

GSHP Cooling Deployment Across India's Various Climates

Regional studies include those by Chedwal and colleagues and Shahare and Harinarayana, which evaluated GSHP applications in Rajasthan and Gujarat, respectively.^{31,32} Roy and colleagues conducted detailed simulations across 10 cities, including five Indian locations—New Delhi, Jodhpur, Chennai, Bengaluru, and Srinagar—each representing distinct climate zones and soil characteristics. Their findings indicate that except for Srinagar, the deployment of GSHPs in Indian cities would require hybrid systems and custom designs to ensure economic viability.³³ Aggarwal and colleagues echoed these thoughts, emphasising that geothermal space conditioning in India remains in its nascent stages.³⁴ They highlight the country's predominantly hot and humid climate, suggesting that building designs must account for high cooling demand and peak load mitigation through an in-depth understanding of building physics. Optimisation of GSHP systems must be building specific, taking into consideration local climate, seasonal variation, soil properties, and both space cooling and hot water requirements.

More advanced fifth-generation DCNs distribute ambient-temperature heat-transfer fluids through a shared-loop connected to borehole fields or aquifers (see **Figure 4.6**). Each connected building has its own small heat pump that extracts or rejects thermal energy as needed.³⁶ These ambient networks require no insulation, reduce operational losses, and decentralise power use—making them ideal for integrating with solar photovoltaics. Clients are responsible for their own electricity use, which simplifies financial models and allows for demand balancing across residential, institutional, and commercial cooling loads.



GEOTHERMAL COOLING AND HEATING NETWORK

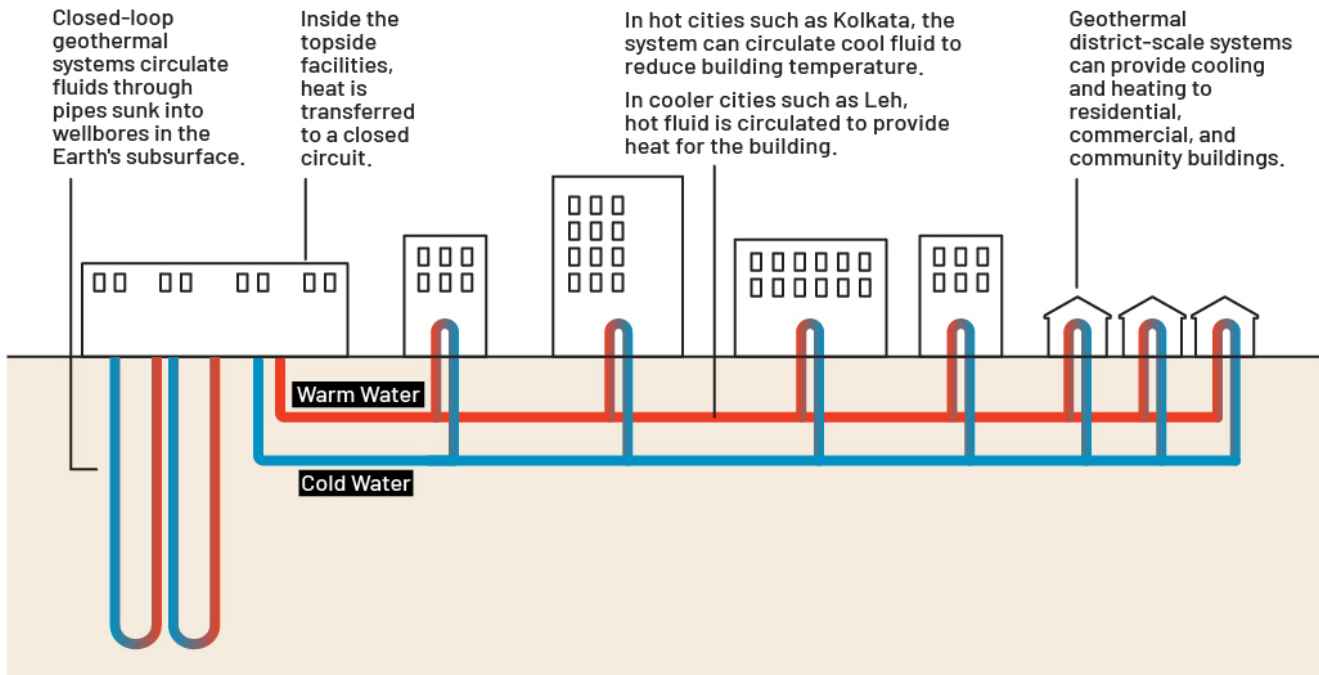


Figure 4.6: District heating system fluid is typically brought to the surface at a target temperature of around 21°C. That fluid is then passed through a heat pump to provide hot water in the winter for heating and cold water in the summer for cooling. This style of heating and cooling can be more than twice as efficient as traditional HVAC systems as the thermal load is shared between buildings. Source: Adapted from U.S. Department of Energy. [Geothermal district heating and cooling](#).

INDIA'S CLIMATE ZONES



Climate type	Summer temperature	Winter temperature	Relative humidity
Hot and dry	20°C–45°C	0°C–25°C	55%
Warm and humid	25°C–35°C	20°C–30°C	70%–90%
Composite	27°C–43°C	4°C–25°C	20%–25% (dry) 55%–95% (wet)
Temperate	17°C–34°C	16°C–33°C	<75%
Cold	17°C–30°C	-3°C–-8°C	70%–80%

Figure 4.7: Map and table showing the different climate zones in India. Source: Adapted from Bureau of Indian Standards (BIS). (2005). [National Building Code of India 2005](#). Government of India; Ozone Cell, Ministry of Environment, Forest and Climate Change. (2019). [India Cooling Action Plan](#). Government of India; Ashok. P. (2025). Evaluation of policy options and recommendation of a phased policy strategy to promote adoption of geothermal ground source heat pumps (GSHP) in India. In *Proceedings of the 2nd Global Conference on Decarbonizing India*. Kerala, India.



REGIONS IN THE BEST POSITION TO LEAD A LARGE-SCALE GEOTHERMAL AQUIFER COOLING REVOLUTION

Project InnerSpace

India's wealth of sedimentary aquifers with subsurface temperatures above 90°C provides a rare opportunity for large-scale cooling across entire regions. So, which parts of India are best suited for this kind of geothermal cooling—and which areas need it the most?

Project InnerSpace overlaid India's regional-level heat risk, as assessed by CEEW, with geothermal resource estimates from the Project InnerSpace Heat in Place model to identify priority areas that are suitable for aquifer-based geothermal district cooling. (This temperature represents the minimum threshold typically required for efficient operation of the geothermal-driven absorption chillers used in district cooling.) This approach ensures that cooling is targeted to sites with both the greatest need and opportunity. It also provides a replicable, data-driven framework for evaluating which of India's vulnerable regions would most benefit from this infrastructure.

The good news is that high aquifer cooling potential aligns with extreme heat risk in a number of important areas across India. Some districts—such as Gandhinagar (28.3 gigawatts), Anand (27.7 gigawatts), Pilibhit (19.1 gigawatts), and Kolkata (17.2 gigawatts)—stand out as strategic hot spots that are vital to target. About 100 other regions also show great potential, making them strong candidates for geothermal cooling technology.

The success of the Indian Army's Net Zero Energy Building in Jhansi—coupled with the urgent need to decarbonise India's cooling infrastructure—means geothermal cooling networks offer an excellent opportunity for cooling that could be implemented soon. Although district cooling leverages centralised chilled-water systems to serve multiple buildings, areas with deep sedimentary aquifers have an added advantage. Deep sedimentary aquifers are present in many major Indian basins (e.g., Cambay, Krishna-Godavari, Cauvery) and can function as powerful heat sinks, taking advantage of the naturally cool subsurface temperatures to distribute chilled water via underground networks—a technique known as *aquifer thermal energy storage*. These networks are widely deployed in Europe for heating and could easily be deployed in India for cooling.

This study used the Project InnerSpace Heat in Place model to screen aquifers to a depth of 3,500 metres so we could identify the ones that would be most effective. Because the absorption chillers used in geothermal cooling typically require inlet temperatures near 90°C to operate efficiently and reliably,³⁷ only aquifers at or above this temperature were selected to ensure consistent output, particularly during peak summer demand. This cutoff guarantees that selected aquifers can deliver scalable, grid-independent cooling in areas where high heat risk overlaps with critical cooling needs.³⁸ Resource estimates were generated for each high-risk district and expressed in gigawatts—a metric that can be linked to the district's cooling demand and energy planning.

RESULTS

Heat-Risk Distribution

The Composite Heat Risk Index calculated by CEEW classifies 417 areas—representing 76% of India's population—as either high risk or very high risk. These districts are concentrated in the following areas (see **Figure 4.1**):

- **Western India:** Gujarat and Rajasthan experience frequent heat waves, expanding urban heat islands, and significant humidity rise inland.
- **Southern Peninsular states:** Andhra Pradesh, Tamil Nadu, and Karnataka have seen a rise in both daytime and nighttime temperatures, particularly in midsize cities (typically defined as having populations between 100,000 and 1 million people).
- **Central and Northern Plains:** States such as Maharashtra, Madhya Pradesh, Bihar, and Uttar Pradesh experience the dual burden of heat and socioeconomic vulnerability, particularly in agrarian or rural communities where adaptive capacity remains limited.

The study confirms that urbanising districts with high population density and built-up area growth—such as Ahmedabad, Delhi, Nagpur, and Guntur—are at the greatest risk due to compounding heat hazards and infrastructure constraints.³⁹



Geothermal Potential from Sedimentary Aquifers

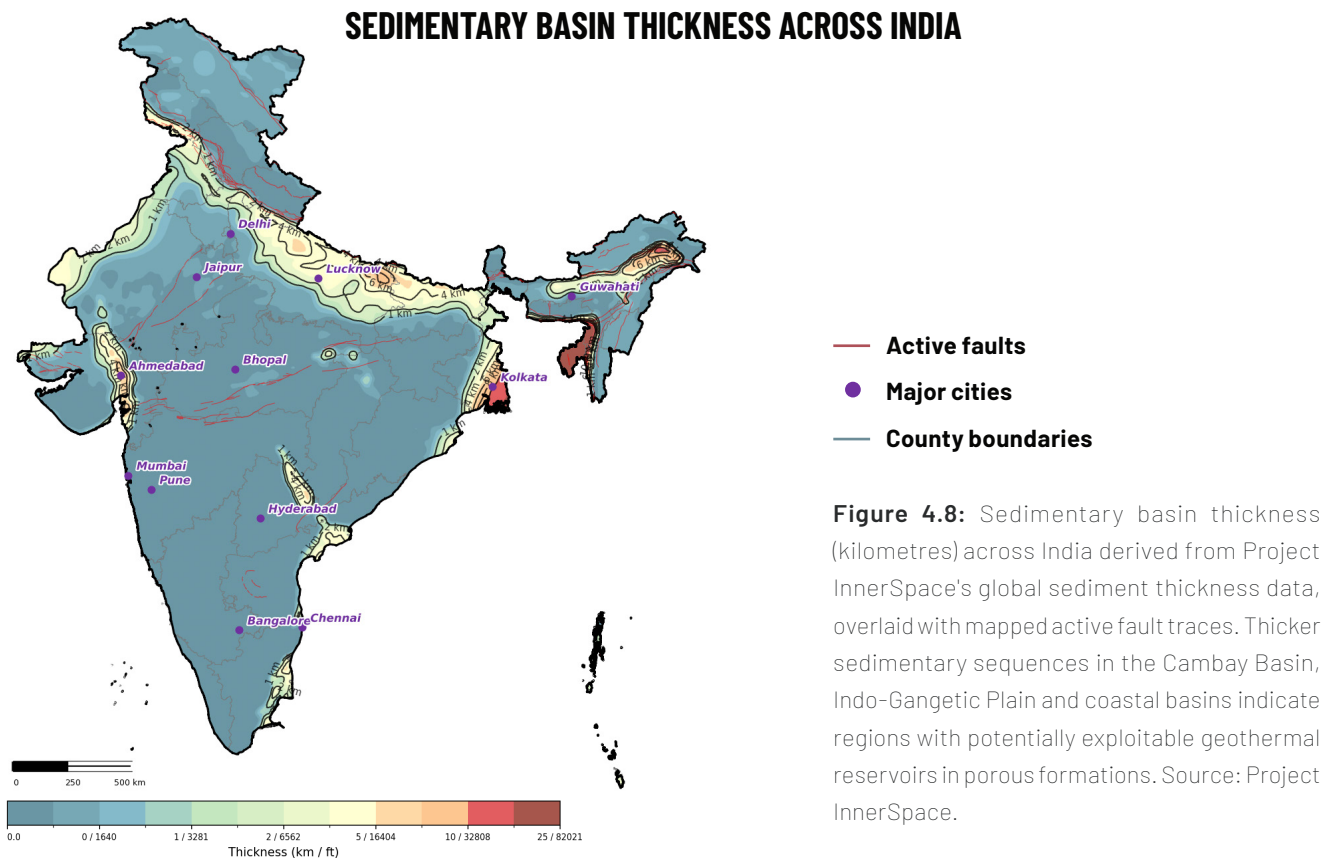
India’s aquifer cooling potential varies widely across states and is closely linked to the distribution of major sedimentary basins. Overall, we estimate a total potential capacity of more than 1,500 gigawatts of cooling using a spacial resolution of 10 square kilometres or per pixel. The Cambay Basin in Gujarat (542 gigawatts) shows the highest aquifer cooling potential in the country due to basin size and sediment thickness. Leading districts include Bharuch (101 gigawatts), Banas Kantha (92 gigawatts), Mahesana (72 gigawatts), Anand (52 gigawatts), Kheda (47 gigawatts), Patan (46 gigawatts), Ahmadabad (43 gigawatts), and Surat (41 gigawatts). These regions have thick quaternary and tertiary sediments, which can support both seasonal and continuous cooling applications in urban and industrial zones.

The Bengal Basin, covering West Bengal (260 gigawatts), shows the second-highest potential nationally. Key districts include South Twenty Four Parganas (100 gigawatts), North Twenty Four Parganas (43 gigawatts),

Purba Medinipur (36 gigawatts), Nadia (31 gigawatts), and Hugli (25 gigawatts). These areas are well suited for urban cooling systems, cold chain infrastructure, and climate-adaptive urban planning, especially around Kolkata and the broader Bengal delta. The Ganges Basin—beneath Uttar Pradesh (142 gigawatts) and Bihar (76 gigawatts)—shows substantial aquifer cooling potential due to basin extent and sediment thickness.

Parts of Tripura (117 gigawatts) and Assam (110 gigawatts) also have significant potential. Key districts include Dhalai (22 gigawatts) and Gomati (18 gigawatts) in Tripura, and Karimganj (18 gigawatts) and Cachar (15 gigawatts) in Assam. Telangana (76 gigawatts), not previously identified in the analysis, emerges as a significant contributor. Districts such as Mulugu (24 gigawatts), Bhadradi (23 gigawatts), and Jayashankar (13 gigawatts) show notable aquifer cooling potential linked to the Pranhita–Godavari Basin.

Rajasthan (85 gigawatts) shows substantially higher potential than previously estimated (was 5 gigawatts), driven primarily by Jaisalmer (73 gigawatts) in the Barmer–Jaisalmer Basin.



In Tamil Nadu (39 gigawatts), high aquifer cooling potential is concentrated in the Cauvery Basin, with Cuddalore (21 gigawatts) as the leading district. Andhra Pradesh (46 gigawatts) contributes through the Krishna-Godavari Basin, with West Godavari (21 gigawatts) and Krishna (12 gigawatts) as leading districts. Jammu and Kashmir (19 gigawatts), partially underlain by the Indus Basin, supports local aquifer cooling.

Low-Potential States and Target Areas

In contrast, states with limited sedimentary cover or predominant hard rock geology—such as Chhattisgarh (2.0 gigawatts), Himachal Pradesh (0.78 gigawatts), and Madhya Pradesh (1.4 gigawatts)—show modest to low cooling potential. These regions may support small-scale or pilot projects. Similarly, coastal and island regions such as the Andaman and Nicobar Islands (0.06 gigawatts) and Haryana (0.19 gigawatts) present negligible potential due to limited aquifer extent.

For this reason, development should focus on deep sedimentary basins—especially the Cambay, Bengal, Ganges, Pranhita-Godavari, and Cauvery basins—where aquifer cooling can be integrated into urban resilience strategies, energy-efficient infrastructure, and sustainable groundwater management.

Target Areas: Where Heat Risk and Cooling Potential Align

By combining the findings shared earlier, we have identified the key areas in India where geothermal aquifer cooling can provide critical relief in the face of extreme heat. Of these areas, Gujarat clearly emerges as the area that would benefit the most, with districts such as Bharuch (101 gigawatts), Mahesana (72 gigawatts), Anand (52 gigawatts), Kheda (47 gigawatts), Patan (46 gigawatts), Ahmadabad (43 gigawatts), and Surat (41 gigawatts) showing particular promise.

In the Ganges Basin, districts in Uttar Pradesh—Sitapur (9.5 gigawatts), Kushinagar (9.4 gigawatts), and Bahraich (7.9 gigawatts)—also exhibit both aquifer potential and extreme heat exposure.

In the coastal and deltaic regions, Tamil Nadu's Cauvery Basin (Cuddalore [21 gigawatts] and Ramanathapuram [3.2 gigawatts] and West Bengal's Bengal Basin (Kolkata [0.91 gigawatts], Bankura [0.02 gigawatts], and Puruliya [0.00 GW]) have promise.

Overall, this study establishes a replicable framework for district-scale geothermal cooling assessments. Future work should focus on enhancing the hydrogeological characterisation of promising districts

ESTIMATED AQUIFER COOLING POTENTIAL ACROSS INDIA AT 3,500 METRES DEPTH

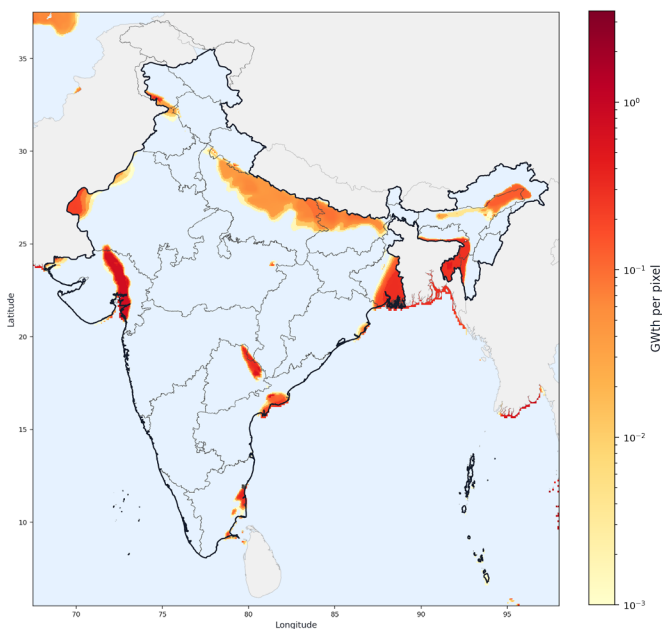


Figure 4.9: This map illustrates the theoretical aquifer-based cooling potential (in gigawatts [GWth] per pixel ~10 km²) across India to a depth of 3,500 metres, based on subsurface properties. Zones with higher cooling potential (shown in red) are concentrated in regions such as Gujarat, West Bengal, parts of Uttar Pradesh, and coastal Tamil Nadu. The spatial analysis highlights areas with significant opportunity for aquifer systems for sustainable cooling applications. Source: Project InnerSpace analysis, 2025.



TOTAL AQUIFER COOLING POTENTIAL BY INDIAN STATE IN GIGAWATTS

Thermal energy potential (GWth) in sedimentary basins at 0–3.5 km depth. MC P50 values.

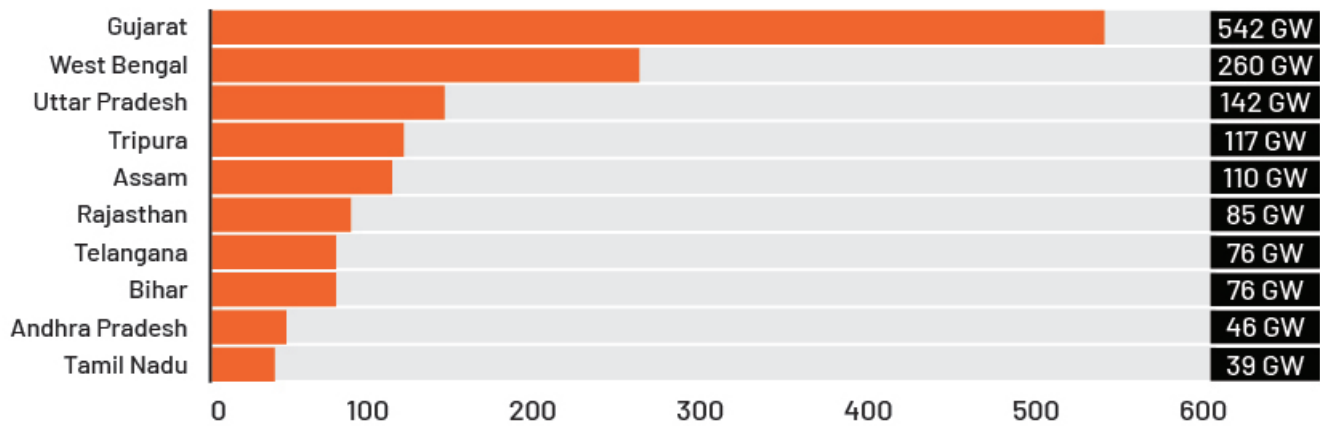


Figure 4.10: This bar chart quantifies the cumulative aquifer cooling potential by state in India to a modeled depth of 3,500 metres. Uttar Pradesh, Gujarat, Bihar, and West Bengal emerge as the leading states, each with more than 100 gigawatts (GWth [per pixel ~ 10 km²]) of estimated thermal energy storage potential. These high-potential regions align closely with the spatial hot spots shown on the corresponding aquifer cooling potential map (Figure 4.9). This analysis supports strategic planning for large-scale deployment of aquifer cooling systems across India. Source: Project InnerSpace analysis, 2025.

(for instance, from national geophysical surveys and borehole data), integrating local feasibility studies and drilling logistics, building capacity for local governments, and conducting pilot demonstration projects in high-priority urban zones.

The findings of this study demonstrate that geothermal cooling—particularly from sedimentary aquifers in high heat-risk districts—offers a viable, scalable, and powerful low-carbon alternative that can help meet India’s growing needs with an estimated 610 gigawatts

of total cooling potential in high-risk areas—and more than 1,500 gigawatts everywhere. Results show that several dozen high-risk districts across western, southern, and central India possess significant geothermal reserves, with leading areas such as Ahmedabad, Guntur, and Tirunelveli offering energy-rich opportunities for district-scale or institutional geothermal deployment.



GEOTHERMAL COOLING POTENTIAL PER DISTRICT AT 3,500 METRES DEPTH

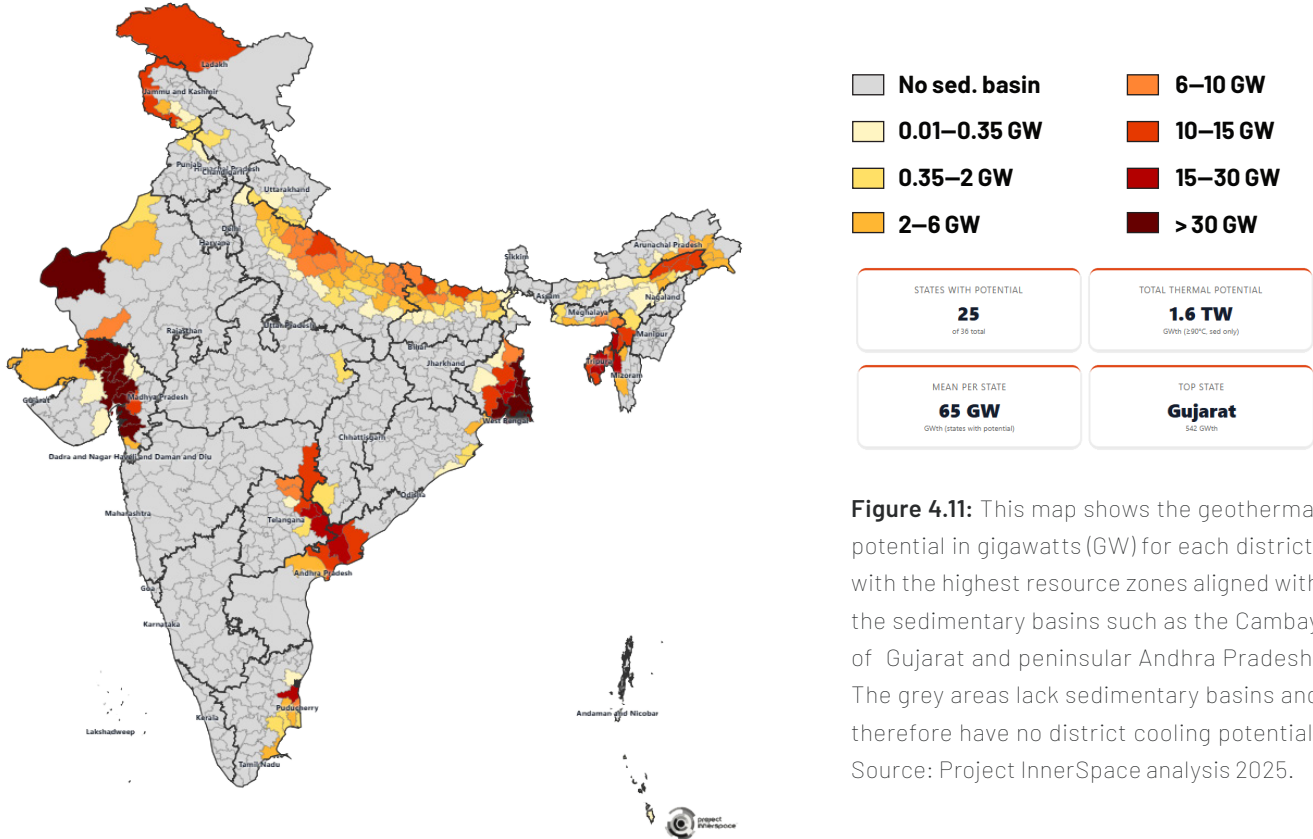


Figure 4.11: This map shows the geothermal potential in gigawatts (GW) for each district, with the highest resource zones aligned with the sedimentary basins such as the Cambay of Gujarat and peninsular Andhra Pradesh. The grey areas lack sedimentary basins and therefore have no district cooling potential. Source: Project InnerSpace analysis 2025.

DISTRICTS WITH ALIGNMENT OF AQUIFER COOLING POTENTIAL AND HIGH DEMAND DUE TO EXTREME HEAT

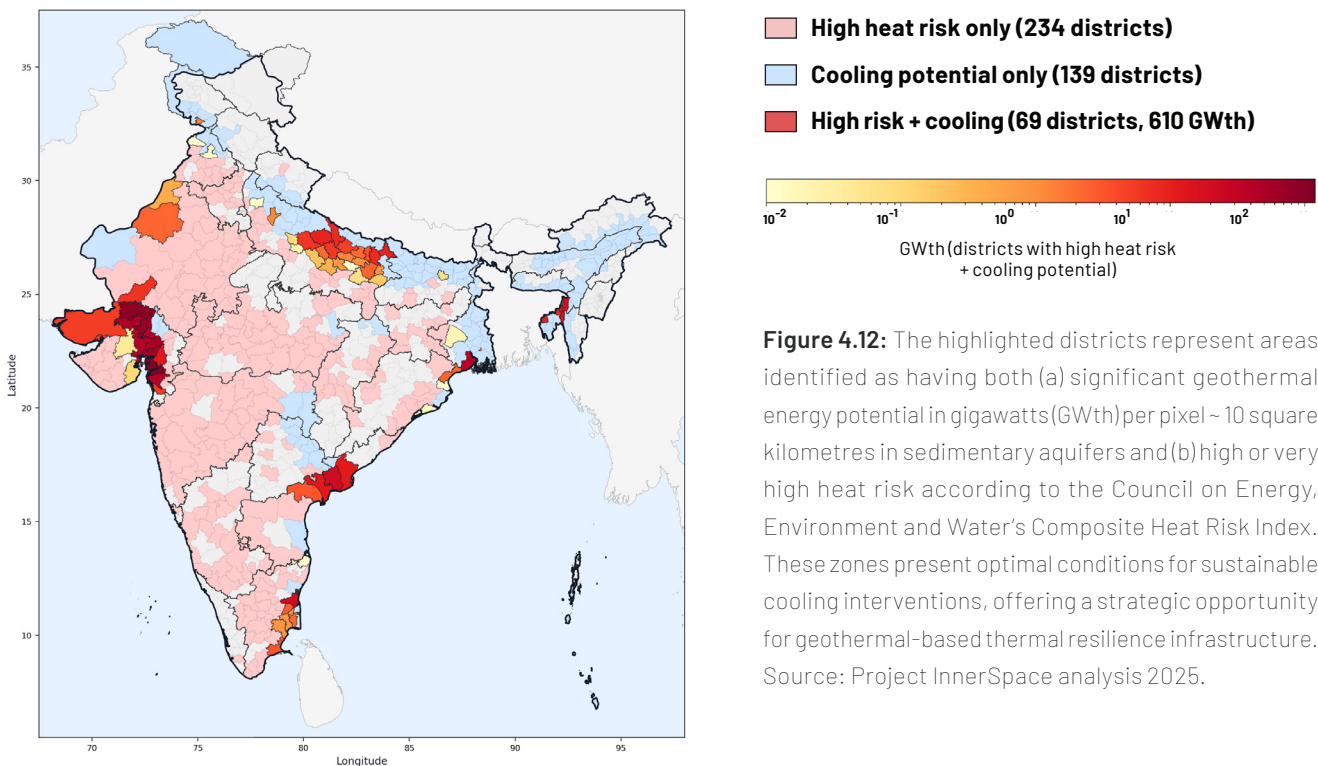


Figure 4.12: The highlighted districts represent areas identified as having both (a) significant geothermal energy potential in gigawatts (GWth) per pixel ~ 10 square kilometres in sedimentary aquifers and (b) high or very high heat risk according to the Council on Energy, Environment and Water’s Composite Heat Risk Index. These zones present optimal conditions for sustainable cooling interventions, offering a strategic opportunity for geothermal-based thermal resilience infrastructure. Source: Project InnerSpace analysis 2025.



BENEFITS OF GEOTHERMAL COOLING

Geothermal represents a major opportunity to help India meet the goals outlined in the India Cooling Action Plan and produce additional important benefits. Developing a national geothermal cooling mission and cooling goals will help unlock the following benefits:

- **Increased climate resiliency:** Geothermal cooling options deliver efficient and round-the-clock cooling, reduced strain on local grids, and the ability to operate off-grid when paired with solar and storage—ensuring cooling remains operational even if the grid is under stress.
- **Enhanced equity:** Geothermal cooling expands access to safe, affordable cooling, ensuring benefits to people across India.
- **Prioritisation of high-heat-risk areas:** Sedimentary aquifers in basins such as Cambay, Cauvery, Bengal, and Indus align with extreme heat districts, enabling deployment where need and resource overlap.
- **Cleaner air and demand relief:** Geothermal cooling replaces conventional air-conditioning with high-efficiency, low-carbon systems that slash cooling-related electricity use and pollution, avoiding close to 810 metric tonnes of CO₂e annually by 2037. It also shifts energy loads to the subsurface, which cuts peak-hour demand, eases blackout risk, and limits the need for new transmission infrastructure and costly power plants that provide electricity only during periods of high demand.
- **Urban-fit and scalable:** Borehole and aquifer systems have modest footprints, can integrate with dense districts and campuses, and can scale from single buildings to ambient-loop networks.

SPACE HEATING AND COOLING LAYOUT OF INDIRA PARYAVARAN BHAWAN

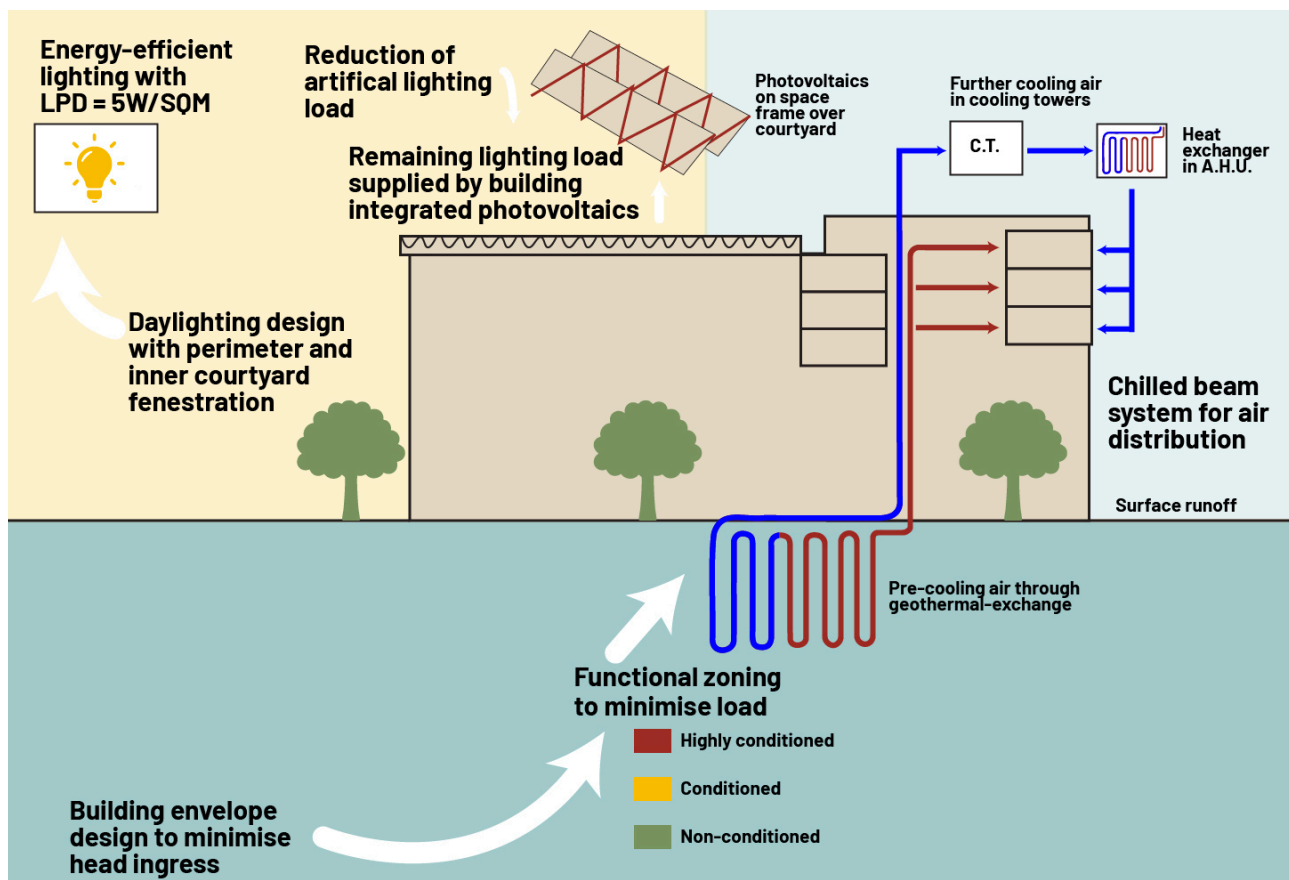


Figure 4.13: Space heating and cooling layout of Indira Paryavaran Bhawan. Source: Khandelwal, R., Jain, R. K., & Gupta, M. K. (2020). [Case study: India's first net-zero energy building—Indira Paryavaran Bhawan](#). *International Journal of Scientific & Technology Research*, 9(11), 353–357.



GSHP AND DISTRICT COOLING NETWORK INSTALLATION IN INDIA

GSHPs are a mature technology that has been deployed across the globe. In recent years, GSHPs have been installed in some limited locations in India. Policies and regulatory support for how to reduce up-front costs and expand this technology in India (such as financial incentives, research and development funding, and vocational programs) are detailed in Chapter 8, “Policy and Regulatory Pathways to Catalyse Geothermal in India.”

The following examples illustrate shallow geothermal cooling systems currently operating in India. These differ from the deep aquifer cooling approaches described in the previous section, which rely on sedimentary aquifers at depth. In contrast, these shallow systems use relatively short boreholes or groundwater loops to exchange heat with the near-surface subsurface. They do not depend on specific

aquifer conditions or deep geological structures. Instead, they draw on the naturally stable temperatures found at modest depths to deliver efficient, low-energy cooling for buildings. The case studies in this section show how such shallow geothermal systems are already being deployed across India.

Indira Paryavaran Bhawan, New Delhi

This building—which houses the Ministry of Environment, Forest and Climate Change—is India’s first on-site net-zero energy building (see **Figure 4.13**). It employs a vertical closed-loop geothermal heat exchange system made up of 180 boreholes, each 80 metres deep and spaced 3 metres apart. Each borehole was also built to reduce reliance on traditional cooling towers. This system contributes to a 40% reduction in electricity consumption and a 55% decrease in water use compared with conventional designs.⁴⁰

SPACE CONDITIONING USING GEOTHERMAL ENERGY AT ISB MOHALI

- 1 At the ISB’s new campus in Mohali (one of the buildings pictured here), cold water from a ‘chiller plant’ circulates through the building, absorbs heat, reaches high temperature
- 2 The heated water passing again through the chiller plant, reaches the heat exchanger
- 3 The geothermal exchanger cools the water as it flows through an underground network of pipes
- 4 Cooled water goes back into the building

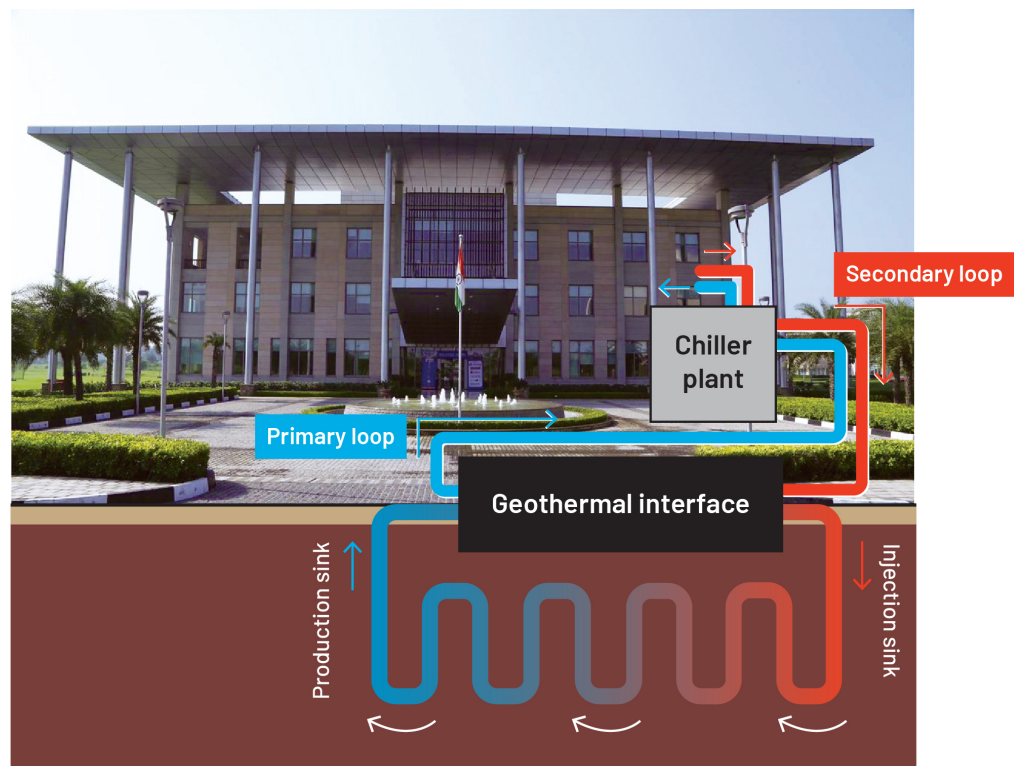


Figure 4.14: Space conditioning using geothermal energy at ISB Mohali. Source: TCBU Editorial. (2020, April 2). [ISB Mohali inducted as India’s most energy efficient building](#). Thermal Control Business Update.



Indian School of Business (ISB), Mohali, Punjab

ISB Mohali has implemented a closed-loop geothermal HVAC system with zero water discharge covering its 70-acre campus, as shown in **Figure 4.14**. This system leads to a 30% reduction in electricity use and conserves approximately 13 million litres of water annually. The campus also features white rooftops to minimize the heat island effect, and it has received multiple accolades, including the Smartest Educational Building in India and the Best Green Campus Award.⁴¹

ACC Hostel Facility, Thane, Maharashtra

This facility uses an open-loop geothermal heat pump system that leverages groundwater at 28°C for air-conditioning purposes. This approach significantly reduces the electrical load required for cooling, showcasing an effective application of geothermal energy in a tropical climate.⁴²

CHALLENGES TO GROUND SOURCE HEAT PUMP ADOPTION IN INDIA

Despite the many benefits of GSHPs, they face some hurdles to adoption in India: The drilling and piping requirements for ground-loop installation mean initial costs can be high; while these systems are suitable for all climates, the return on investment timeline will depend on climate and soil conditions; there have not yet been enough installations to make the case to would-be investors that this technology is financially viable. The installation of these systems can also be complex by requiring understanding of geology, and it can take longer than traditional HVAC systems. In the United States and Europe, however, many companies are working to address these barriers.

Another significant barrier in India is the shortage of technical expertise required for the design and implementation of GSHP systems; only a few companies are currently capable of delivering such solutions. Chapter 5, “Leveraging Oil, Gas, and Mining Technologies and Workforce to Advance Geothermal in India,” addresses how to overcome barriers to the limited workforce. Chapter 8, “Policy and Regulatory Pathways to Catalyse Geothermal in India,” discusses solutions to reduce up-front costs.

DIRECT USE FOR SPACE HEATING

Given India’s climate, the majority of this chapter focuses on geothermal as a cooling solution. However, the same technologies can be deployed for heating. (See Chapter 1, “Geothermal 101: Overview of Geothermal Technologies and Applications.”)

In high-altitude regions such as Ladakh, where temperatures can plummet below -20°C, the Indian Army currently relies heavily on diesel generators for heating, leading to substantial logistical challenges and environmental concerns. Implementing geothermal-based space heating systems in these areas can offer a sustainable alternative, reducing diesel consumption and associated emissions.

Developed by the Defence Research and Development Organisation, the Snow and Avalanche Study Establishment near Manali, Himachal Pradesh, marks India’s first significant closed-loop geothermal space heating system. The system comprises 27 boreholes with a total length exceeding 2,500 metres, connected to a reverse cycle water-to-water heat pump. Operating at an output load capacity of about 115 kilowatts, it maintains indoor temperatures between 30°C and 32°C in winter and between 18°C and 19°C in summer, with a ground entry temperature between 13°C and 19°C. The system achieves an annual carbon emission reduction of 14.2 tonnes and has a payback period of approximately five to six years.⁴³

India’s largest geothermal space conditioning system is already in development at Ladakh’s Leh Airport, using 457 boreholes for year-round temperature control.⁴⁴ A pilot geothermal heating project is also being implemented in the hospitals of Kargil, a city in Ladakh.⁴⁵ Globally, projects such as Beijing’s Linked Hybrid complex (which uses 655 geothermal wells for 70% of its heating and cooling^{46,47}) and Iceland’s widespread geothermal district heating systems showcase the scalability and sustainability of geothermal heating systems.

Adopting similar systems in India’s cold regions can enhance energy security and operational efficiency for military installations.



THE INDIA COOLING ACTION PLAN AND POLICY FRAMEWORK

As mentioned, the Ministry of Environment, Forest and Climate Change has put together the ICAP to address India's cooling needs through active engagement with multiple stakeholders.⁴⁸ Some of the goals identified in the plan for achievement by 2038 include reducing the overall need for cooling by between 20% and 25%, reducing the amount of energy needed for cooling by between 25% and 40%, and reducing refrigerant demand by between 25% and 30%.

To meet these goals, the ICAP recommends various intervention strategies; as of 2024, India has made measurable progress toward achieving these goals. The Bureau of Energy Efficiency issued an advisory to set the minimum air-conditioner temperature at 24°C and implemented Minimum Energy Performance Standards, along with a star rating and labelling program. New efficiency standards were introduced for room air conditioners, and e-market initiatives encouraged the production of efficient models. Together, these measures helped reduce energy consumption by about 10 terawatt-hours (to 188 terawatt-hours in 2022–23).

While the ICAP has not yet mentioned employing direct-use geothermal technologies to meet cooling demand, India's geothermal resources have the potential to be transformative in the nation's strategy. To better advance direct-use applications, India could also adopt several policies that translate the technical potential mapped in this chapter into steel-in-the-ground projects. Chapter 8, "Policy and Regulatory Pathways to Catalyse Geothermal in India," recommends that India adopt a national geothermal cooling mission as part of the ICAP to jump-start geothermal cooling across the country. Potential targets include between 800 megawatts and 1 gigawatt (thermal) for cooling by 2035, between 3 gigawatts and

4 gigawatts by 2040, and more than 10 gigawatts by 2050. The mission should also prioritise locating district cooling networks in districts such as Cambay, Cauvery, Bengal, and Indus basin cities that have overlapping heat risk and sedimentary basin potential. These targets could be formally nested under the ICAP, which could ensure that geothermal district cooling and GSHPs count toward the ICAP's demand- and energy-reduction goals.

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Chapter 8 also notes the importance of key parts of India's new geothermal framework, such as advancing pilot projects. Given the importance of cooling in India, it seems logical for some pilots to focus on cooling. Additionally, India could establish a national institute of geothermal energy to lead research on GSHP adaptation across India's diverse climatic zones and soil types. This research—combined with cooling pilot projects and other related recommendations outlined in Chapter 8—could enable the widespread adoption of geothermal cooling, ensuring equitable access and optimised system performance across different regions.





CONCLUSION

As India confronts the intensifying impacts of extreme heat—now a chronic climate hazard affecting more than 400 districts and three-quarters of the country's population—the country has a pressing need to expand beyond conventional, energy-intensive cooling technologies. By undertaking such expansion, India could emerge as a leader in climate resilience. With rising temperatures, the severe risks to human health, agriculture, and the national GDP are growing sharply. At the same time, conventional strategies for cooling are failing.

Fortunately, India's geography offers a sustainable alternative. Thanks to the country's sediment-rich basins, geothermal cooling is not merely a technical possibility—it is an urgent adaptation imperative.

Heat from the Earth is a renewable, domestic energy source, and extracting that energy not only helps reduce

carbon emissions but also can address India's growing energy needs and shortage in fuel supply. Investing in research and development, focusing on each region's unique needs, and subsidising the development of geothermal are all essential to the country's future. In the long run, these efforts will help bring costs down, promote a home-grown supply chain, and develop a workforce with the necessary knowledge about the technology. Nonprofits and philanthropic organisations have greatly assisted with the development and monitoring of a cooling plan, and their support can be critical for the widespread adoption and deployment of geothermal-based cooling solutions in India.

By harnessing the transformational power and potential of geothermal cooling in key regions, India can create a long-term, sustainable strategy for cooling at a time when solutions are desperately needed.



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