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STUDY OF OPPORTUNITIES FOR STRATEGIC DEVELOPMENT OF GEOTHERMAL ENERGY IN INDIA

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ABSTRACT

With the expected increase of two major drivers, i.e. GDP and population, energy demand in India will roughly double by 2040. This energy demand is expected to be met by thermal sources which means that CO_2 emission may increase from 7% of the world emission today to 14%. As a part of Paris Climate Agreement, India set the goal to generate 40% of its cumulative energy demand from non-fossil fuels by 2030 by promoting the use of renewable energy sources. Among various sources of renewable energy, the exploration and development of geothermal energy could contribute to India's energy switching plan. The purpose of this study was to identify opportunities for strategic development of geothermal energy in India as part of the energy mix. The Geological Survey of India has identified 350 geothermal prospects in the country with surface temperatures in the ranged 37-90°C. Most of these zones are elongated, spanning several hundred kilometres in length. Despite being low enthalpy, it is anticipated that these resources could significantly contribute through various direct use applications.

The present work regards the lack of geothermal legislation in India as a significant threshold for development. Current legislations / draft policy on geothermal energy development were reviewed in the light of operational in-force policies on other sources of renewable energy. Various important factors which could be improved like assured power purchase agreements, power evacuation, loan guarantee programmes, clearances, lack of clarity in policy and regulatory legislation along with non-availability of data were identified. In this paper we also carry out a policy mapping and stakeholder analysis of India's geothermal energy sector using the PESTLE (political, economic, social, technological, legal, and environmental) approach. Multidisciplinary stakeholders have been identified and their relationship to geothermal development have been described. The outcome of the analysis emphasizes the importance of strategically aligning stakeholders based on policy, regulatory, fiscal incentives, financing, manufacturing, transmission requirement, and priority studies.

The impact on levelized cost of energy (LCOE) by incorporating in-principle incentives from the draft policy for the Puga geothermal power plant was carried out. The model shows an attractive tariff band within saleable range. Cascade direct use can further enhance the financial viability.

1. INTRODUCTION

Social development, generation of wealth and quality of life are highly dependent on the energy supply in both developed and developing nations (Capik et al., 2012). Developing countries, especially the BRIC (Brazil, Russia, India and China) nations, are advancing quickly to transform their energy supply meeting the growing demand. Energy consumption in India is estimated to increase faster than the population growth. It is estimated that out of the total energy requirement in the future, 80% will be met with fossil fuels (Ummadisingu and Soni, 2009). In 2019, out of 358 GW installed capacity, 63.2% of the energy requirement is generated by thermal power plants utilizing coal and gas (CEA, 2019a).

According to its international commitment to mitigate climate change, India intends to pioneer a gradual shift from economic activity based on fossil fuels. to one based on non-fossil fuels (NAPCC, 2019). The Indian government has taken the initiative to switch from coal fired power plants to renewable energy sources (Singh and Sood, 2009; Mishra et al., 2011).

India has started to facilitate this change by strengthening the energy sector in terms of open market, and putting a multi-buyer - multi-seller structure into place associated with an independent regulatory framework. The regulatory framework was set up by the State Electricity Regulatory commission (SERCs) and the Central Regulatory Commission (CERC) to enhance competition, efficiency and economy of the activities associated with electricity generation. Among the available energy sources, India prioritizes the development of hydro, solar and wind power by incorporating attractive features for developers through schemes and policies resulting in growth of the green energy sector. The local governments have been granted extended exemptions, concessions, and soft loans by the central government to ensure an attractive tariff compared to current market rates.

The peak energy demand is expected to rise from the current level to 690 GW by 2035-36 (CEA, 2019b). This demand promotes the exploration of coal resources and import of petroleum contributing to greenhouse gas emission. Thus, in order to meet the increasing demand for energy in the country, massive additions to the installed generating capacity are required by exploration and development of renewable energy sources which have less impact on the environment and reduce the dependability on oil imports. Together with other renewable energy sources, geothermal is an alternate, renewable, environment-friendly sustainable source of energy.

The Geological Survey of India has compiled a list of 340 hot springs across the country (Krishnaswamy and Ravishanker, 1982) categorized into seven geographical provinces (Padhi and Pitale, 1995) as shown in Figure 1. The figure shows that most of these hot springs are located in remote areas along the Himalayan belt, in Northeast India, in Central India and along the West coast. While geothermal is given high priority in the resource mix by many countries in the world, India has so far been satisfied with small-scale development. To make geothermal a real option as energy source to meet the local demand, an attractive policy based on a bottom up approach is necessary. In this study, efforts have been made to encapsulate the overall current energy scenario in India along with potential uses of geothermal prospects in local areas based on their key economic activities. This study also analyses current policy on renewable energy sources in India with regard to geothermal for overcoming barriers and enhancing the financial viability. Strategic development of geothermal energy is the main focus of this study which is based on studies of major constraints in geothermal energy development using the PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) analysis.

Since the energy market of India is very competitive, low tariff is an attractive feature for financial closure and sale of energy during project development and after commissioning, respectively. A tariff model is developed based on regulation 8 of the Central Electricity Regulatory Commission guidelines 2019-20. (CERC, 2017).

The subject of this study is to assess the implementation of geothermal energy in India by working on the following research questions:

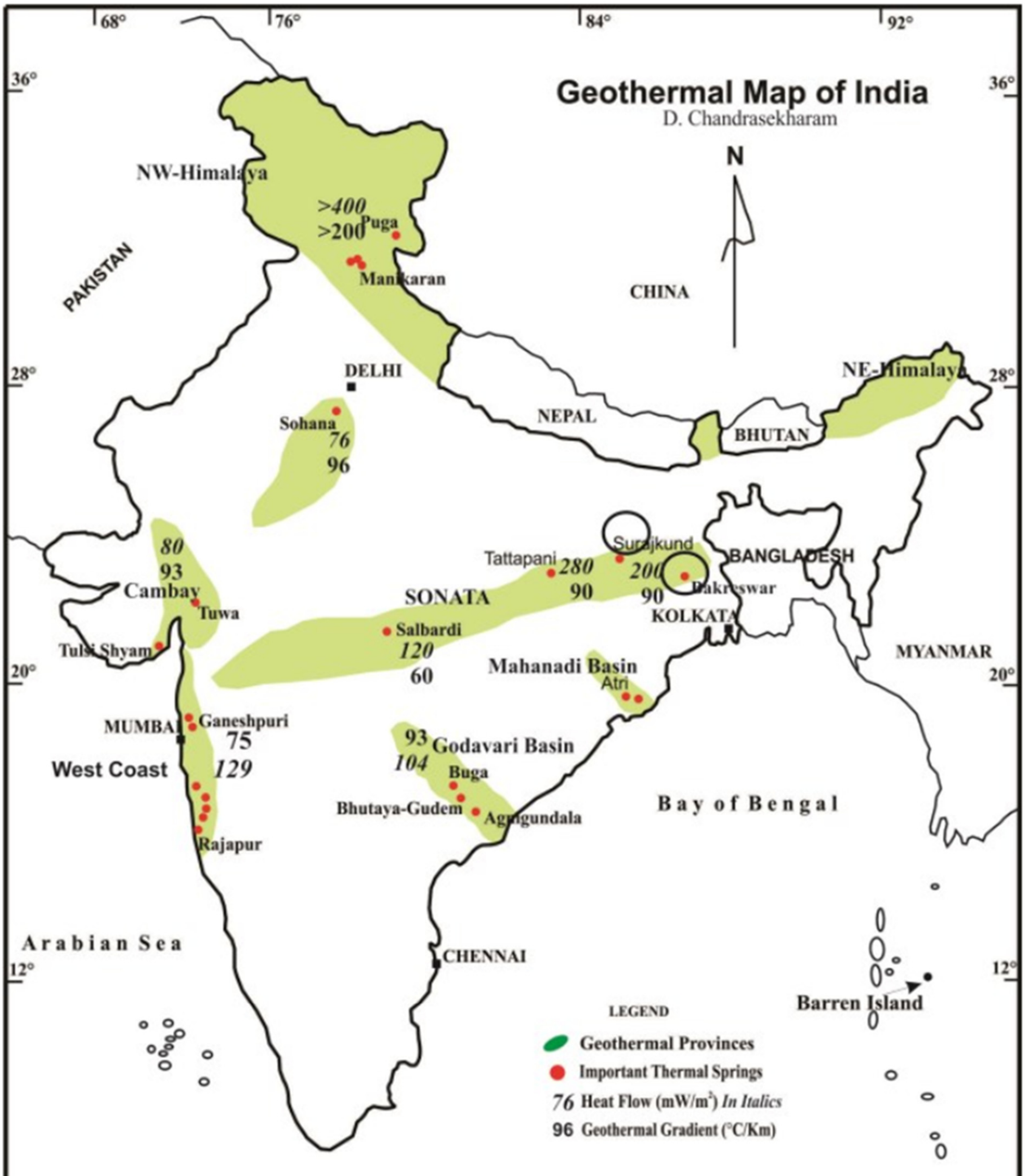


FIGURE 1: Map of India showing the geothermal provinces, heat flow values (mW/m^2: in italics) and geothermal gradients (°C/km). I: Himalaya; II: Sohana; III: Cambay; IV: Sonata; V: West coast; VI: Godavari; VII: Mahanadi (from Chandrasekharam and Bundschuh, 2008)

- Identification of opportunities for harnessing geothermal energy sources across the country.
- Identification of various factors and stakeholders that could influence the development of the geothermal energy sector in India.
- Case studies, through implementing, in principle, policy benefits of the most technically feasible projects integrated with cascaded direct use, based on resource ranking and available input information like design energy and power evacuation cost.

2. RESEARCH METHODOLOGY

In order to map potential areas for geothermal energy use across India, data from the Geological Survey of India along with literature on geothermal prospects is used. The Lindal diagram is used as a tool for depicting various applications of geothermal fluids depending on the resource properties. Current legislation and operational policies on renewable energy along with draft policy on geothermal published in 2019 by the Government of India is reviewed in order to identify key constraints in the development of geothermal energy. Based on those results, measures are suggested that could be included in draft policy.

One of the key objectives of this report is to identify, analyse and categorise the political, economic, social, technological, legal and environmental factors (PESTLE factors). This allows us to map the influence and involvement of key stakeholders. The process adopted using the PESTLE technique covers the following:

1. Brainstorm and enlist the potential key impact factors;
2. Broadly establish the implication of each factor;
3. Stakeholder mapping using PESTLE; and
4. Create power influence matrix to identify key areas.

The study will provide information for decision making based on the various key factors for development of geothermal energy in India.

Tariff (cost per kWh) is a pivot factor in the development of projects in the energy sector. It is crucial for lenders/investors which finance the projects during the early stage of development. This report analyses the impact on the tariff in two different scenarios; with incentives and without incentives. In absence of tariff regulations for geothermal energy, guidelines for the development of small hydropower projects of up to 25 MW have been used, including the following parameters for calculation of design energy and capital cost of the project:

1. Plant capacity: 15 MW (Ahangar, 2012);
2. Plant useful life: 20 years (CERC, 2019);
3. Cost per kW: 2300 USD (IRENA, 2019); and
4. Plant load factor: 75% (IRENA, 2019).

Levelized cost of energy generated (LCOE) is a method to determine the cost of 1 kWh, considering the overall cost for development of a project and maintenance cost known as capital expenditure (CAPEX) and operational expenditure (OPEX), respectively. All costs are summed up and divided by the total discharged energy. The result is the levelized cost of energy generated (LCOE). The levelized tariff over the useful life of the project is calculated based on the norms specified in the Central Electricity Regulatory Commission regulation.

3. CURRENT ENERGY SCENARIO IN INDIA – NEED OF RENEWABLE SOURCES

As per status of energy generation, India is the 3rd largest electricity generating nation worldwide with 5% in global share and is expected to grow to nearly 11% with roughly doubling the figure of CO_2 emission by 2040 (BP, 2019).

On July 31st 2019, the total installed capacity was 357.87 GW with the biggest share, 63.20%, coming from fossil fuels, 1.9% from nuclear power generation and 12.7% of the electricity is generated by large hydro power plants (Figure 2) (CEA, 2019a). About 22% is contributed by renewable energy sources (CEA, 2019a). The annual data shows that overall generation (including generation from grid connected renewable sources) in the country has been continuously increasing with an overall growth rate of 5.19%

from the year 2014-15 until 2018-19 (CEA, 2019b). However, Figure 3 shows that there has been a considerable increase in energy generation from renewable sources but no decreasing trend has been observed in the development of thermal power plants (CEA, 2019a).

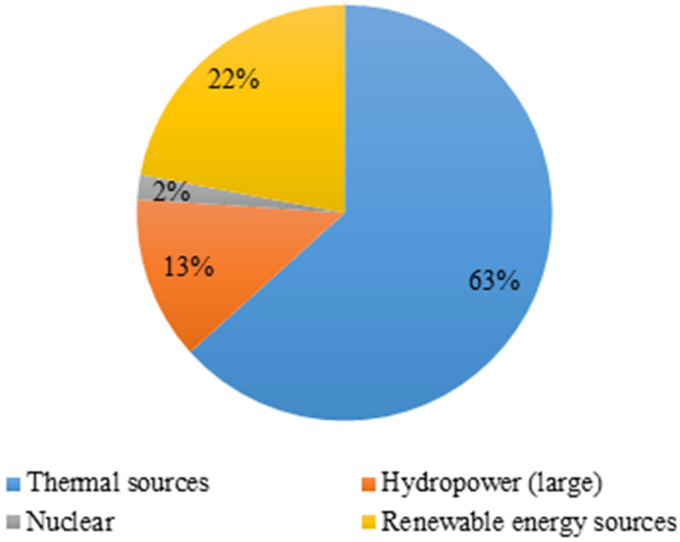


FIGURE 2: An overview of the power sector in India (CEA, 2019a)

Energy in India is produced by three major sectors, the Central sector (Central government Public Sector Undertakings – CPSUs), the State Sector (State government Public Sector Undertakings – SPSUs) and the private sector. The current market shares of the private, central and state sector are 46%, 25% and 29%, respectively. Power consumption by different sectors is shown in Figure 4 (CEA, 2019a; MoS&PI, 2018). Both population and industries are growing rapidly, making India one of the fastest growing economies. In order to meet the energy demand, India is continuously exploring energy sources, the fastest and most economical options available are coal, lignite, natural gas and petroleum for running thermal power plants. Figure 5 shows the annual production of coal, lignite, natural gas and petroleum from year 2007-08 to 2016-17, and is good indicator of the trend (MoS&PI, 2018). The coal production was about 457.08 MTs in 2007-08 and has increased with a CAGR (Compound Annual Growth Rate) of 3.79% to 662.79 MTs in 2016-17. The production from primary sources of fuel like lignite and crude petroleum has increased with a CAGR of 2.90% and 0.54%, respectively. During the aforesaid period, annual generation of electricity increased by 4.05% and consumption of electricity by 7.82%. Therefore, India is likely to remain dependent on coal in the coming years.

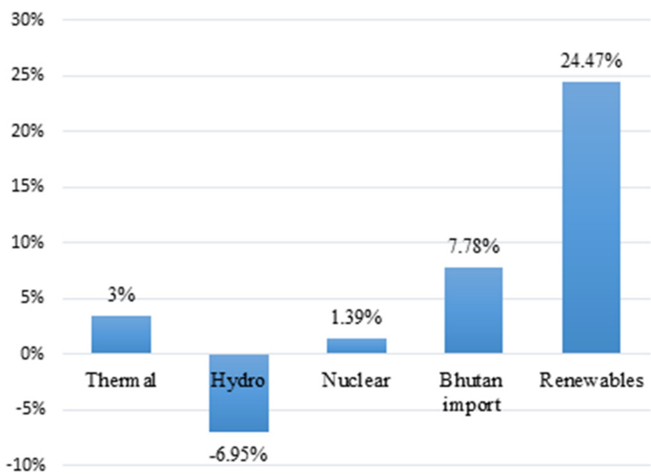


FIGURE 3: Changes in category wise energy production

In its Load Generation Balance Report (LGBR), the Central Electricity Authority (CEA) had projected that India would become a power-surplus nation in 2017-18 (CEA, 2017). Instead, the peak power deficit was 2.1%, while the overall electricity deficit was 0.7% across the country (CEA, 2018). In the LBGR report of 2018-19, the CEA had again predicted

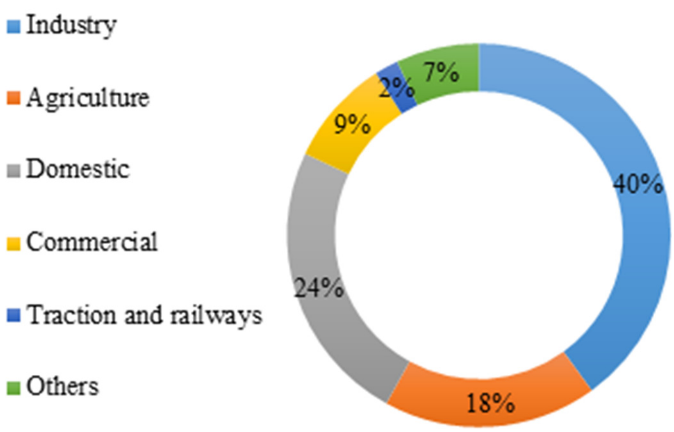


FIGURE 4: Power consumption by various sectors (CEA, 2019a; MoS & PI, 2018)

overall energy and peak power surpluses of 4.6% and 2.5%, respectively, indicating that India would be a power-surplus country in the financial year 2018-19 (CEA, 2018). However, India again missed this target by a whisker as its peak power deficit was 0.8% and the overall energy deficit remained 0.6% in 2018-19 (CEA, 2019b). Considering India's energy consumption, the country is expected to be the fastest growing nation among all major economies by 2035 (BP, 2019). Currently India is focusing on switching to renewable energy sources and the share of renewable energy has increased from 12% to 22% between 2012 and 2019 (MoP, 2019).

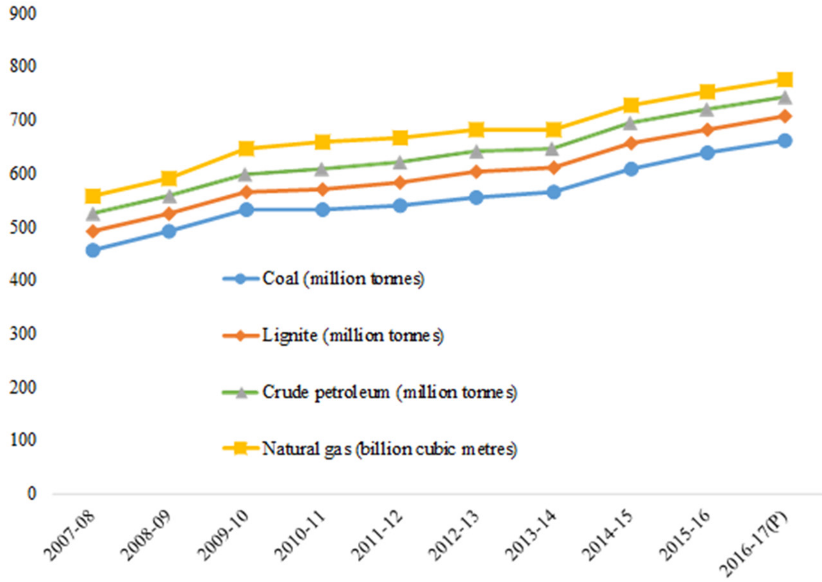


FIGURE 5: Production of carbon based sources of energy (MoS & PI, 2018)

According to potential assessment studies carried out by the Central Electricity Authority, India has an estimated potential of 100 GW of renewable energy excluding geothermal energy sources. Additionally, geological, geochemical, shallow geophysical and shallow drilling data suggest that India has about 10 GW geothermal energy potential that could be harnessed for various purposes. In the run-up to the Paris Climate Change Summit in December 2015, the Indian government announced its target of achieving 175 GW of renewable power by 2022 and 350 GW or 40% of its total installed power capacity through renewable energy sources by 2030 (MoP, 2019). To reach these goals, it is necessary to make full use of renewable energy sources in different sectors of applications to facilitate a gradual shift from economic activity based on fossil fuels to one based on non-fossil fuels.

4. GEOTHERMAL ENERGY IN INDIA-RESOURCE MAPPING

The oil crisis of the 1970's pushed many countries to explore and exploit domestic energy sources which included but were not limited to geothermal energy resources. India like most other countries joined by assessing the geothermal potential across the country. The Geological Survey of India (GSI) carried out a multidisciplinary study in 1973 with the following subjects:

- Identification of geothermal provinces;
- Isotopic composition of geothermal fields;
- Heat flow studies;
- Status of geothermal exploration; and
- Geothermal modelling.

A report was published with the title *Geothermal Energy Resources of India* in year 2002. The report revealed the existence of almost 340 thermal spring (Krishnaswamy and Ravishanker, 1982) which have been grouped into 7 geothermal provinces based on data from geothermal exploration studies such as geological, geohydrological, geochemical and geophysical studies along with exploratory drilling with maximum depth up to 728 m. The geothermal provinces are subdivided into geothermal systems, each with its own structural setup, hydrogeological, geochemical and enthalpy characteristics. The geothermal provinces of India (Figure 1) are:

1. Himalayan;
2. Sohana;
3. Cambay;
4. Sonata;
5. West coast;
6. Godavari; and
7. Mahanadi.

The presence of geothermal resources in India is mainly caused by tectonic features. Some of the main geothermal zones are in the Himalyan stretch from Puga Ladkh in Jammu and Kashmir State, and Manikaran in Uttar Pradesh to Takshing in Arunachal Pradesh (Mandal, 2003). In Central India, promising geothermal resources are located along the Son-Narmada lineament at Anhoni-Samoni, Madhya Pardesh and Tatapani, Chatttisgarh. A linear stretch along the West coast from Koknere in the North to Ganeshpuri, Unhavare, Tural and Rajpur in the South hosts hot springs. Geothermal springs are also located in many other locations such as:

1. Bakreshwar in West Bengal;
2. Tarabola in Odhisa (or Orisa);
3. Manuguru in Telangana;
4. Unai in Gujarat;
5. Garampani in Assam;
6. Takshing in Arunachal Pardesh; and
7. Rajgir in Bihar.

The listed geothermal springs are spread over the whole country and have formed due to local geological conditions (Thussu, 2002).

The main reason for the stagnation of geothermal development in India is the availability of cheap power from coal-based power plants, non-availability of deep drilling machinery and lack of funding. The constraints and development of the geothermal energy resources are discussed in the PESTLE chapter.

4.1 Resource opportunity and potential use across India

The geothermal sources have been used since ancient times, e.g. by the Romans who used the hot water and steam for bathing, cooking and heating buildings. Today, use of water from hot springs is common worldwide for space heating, agricultural and industrial uses and spas (Barbier and Fanelli, 1977). In this section, potential uses of geothermal energy, based on local temperature gradient and heat flow, are analysed. Commercial exploration of geothermal energy for power generation is yet to be taken up in India since most of the resources are of low-enthalpy type. The surface temperature of most of the hot springs varies between 30 and 100°C (Vaidya et al., 2015). Therefore, options need be to be explored how to utilise the sources in direct use applications based on the localised requirements. Direct use refers to the utilizations of geothermal energy other than power generation.

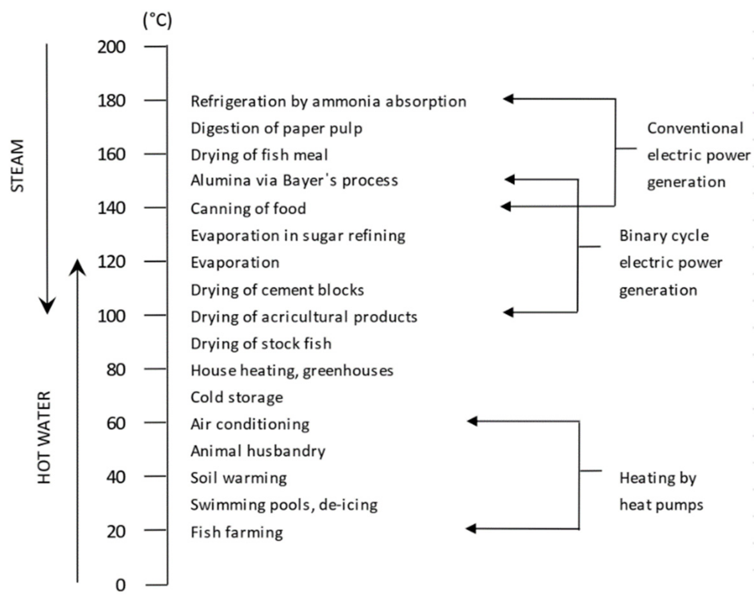


FIGURE 6: Lindal diagram (Gudmundsson et al., 1985)

The Lindal diagram (Lindal, 1973) is used as a tool to identify potential uses in the local environment in addition to resource ranking based on cascaded use (Figure 6). It is an effective way to illustrate the various applications of geothermal fluids depending on the resource temperature. Early version of the Lindal diagram included various uses like de-icing and soil warming, fish farming, swimming pools and balneology, space heating of buildings and greenhouses, organics drying, evaporation and food canning as well as the digestion of paper pulp and refrigeration by ammonia absorption. Recent additions are applications like electrical power production from dry-steam, flash-steam and binary power cycles (Gudmundsson et al., 1985; Lund et al., 2011) The Lindal diagram shows that fluids with temperatures below 100°C are mainly recommended for the use in direct applications while those above 100°C for industrial application.

In order to identify potential uses, major geothermal provinces have been identified and are summarized in Table 1 along with the temperature gradient, heat flow and the nearest catchment areas/ localities.

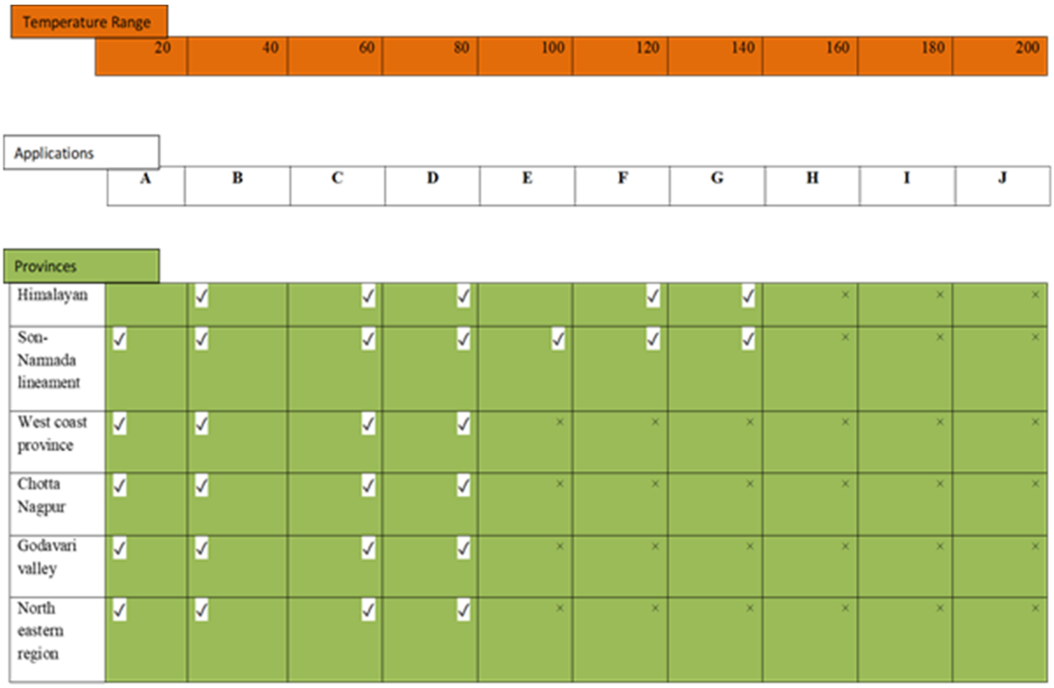
TABLE 1: Summarized data of geothermal provinces (GSI, 1991)

Nos.	Name of geothermal province	Catchment locality	Temperature gradient and heat flow		
			Hot spring temperature (°C)	Borehole data	Thermal gradient
1	Himalayan	Puga Chumthang, Ladak	30-84	13 boreholes drilled - total flow 3000 L/min. and temperatures of 83-123°C	-----
		Manikaran	34-96	8 boreholes temperatures 83-93°C. T_{max}: 100°C	100°C/km
		Tapoban	30-65	Drilled boreholes, T_{max}: 92°C	44-68 °C/km
2	Sonata	Tatapani	52-97	5 boreholes (350 m) with T_{max} 112.5°C	60-100 °C/km
		Anhoni-Samoni	32-45	3 boreholes drilled, T_{max}: 54°C	59°C/km
3	West Coast	West coast, Maharashtra	Unhavre (Khed) and Tural hot springs; T_{max}: 72 and 62°C, respectively	In borehole, T_{max}: 59°C	60°C/km
4	Chotta Nagpur Gneissic complex	Bakreshwar	40-70	2 drilled boreholes T_{max}: 65°C	
5	Godavari valley	Manuguru	36-44	Waters of 50-60°C in Gondwana coal mines	
6	Northeastern region	Assam-Meghalaya	Jakrem, 46°C, in Meghalaya, Garampani, 54°C, in Assam, Takshin, 52°C, in Aru.Pradesh		

Due to the increase in population, industrialization and urbanization, energy demand is expected to rise manifold. It is pertinent to mention that considerable progress has been made in improving the energy access in the country. However, 27 million households still do not have access to electricity (Saubhagya Dashboard, 2019) and 780 million people rely on biomass for cooking. Therefore, it is necessary to exploit and develop alternate sources of energy for the various uses in different energy utilizations sectors. Figure 7 shows potential uses based on the Lindal diagram (Figure 6) and the borehole data from Table 1.

As Figure 7 illustrates, resources in the Himalayan and Son-Narmada have more possibilities with regards to cascaded uses and should be developed first. Potential uses of geothermal energy resources in India are shown in Table 2. It is though advisable to use an approach aimed at policy based on phase and step-wise development of geothermal energy in India.

This summary illustrates that India has considerable potential for use of geothermal energy in a wide variety of fields, apart from power generation. Exploration will establish whether development of the power sector is feasible but currently, geothermal energy is considered a possible substitute for fossil fuels in low- to moderate-temperature uses. Geothermal energy can be used as a source of energy for



"A"- Fish farming. "B" - Swimming pools, De-icing, Soil warming. "C" - Animal husbandry, Air conditioning "D" - Cold storage, Space heating (Building and Greenhouses). "E" - Drying of stock fish, Drying of agriculture products. "F"-Drying and curing of cement blocks, Evaporation/ Binary fluid electric generation. "G" -Evaporation in sugar refining, cleaning of food// Binary fluid electric generation. "H" - Alumina via bayer's process, Drying of fish meal/Binary fluid electric generation. "I"- Digestion in paper pulp. Refrigeration by ammonia absorption

FIGURE 7: Tri-colour diagram with applicable use of geothermal energy across India

TABLE 2: Potential uses of geothermal energy across India

Nos.	Utilization of geothermal energy	Temperature required (°C)	Name of resource areas
1	Binary Power Plant	100-180	Puga - Union territory of India; Tatapani - Chhattisgarh Tapoban - West Bengal; Manikaran - Himachal Pradesh
2	Refrigeration (cold storage plants)	70-100	Cascaded use from the above-mentioned sites may provide suitable conditions for refrigeration by evaporation.
3	Greenhouse	60-80	Manikaran - Himachal Pardesh; Tapoban - West Bengal Puga - Union territory of India; Tatapani - Chattisgarh West coast area; Anhoni - Samoni Madhya Pardesh
4	Food processing	<100	Greenhouse cultivation is possible in Manikaran, Tapoban, Parbati valley, Puga-Chhumthang field, Tatapani, West coast area, Anhoni- Samoni, and Surajkund as well as food process.
5	Snow melting	<80	Puga - Union territory of India; Tapoban - West Bengal Parbati valley - Himachal Pradesh
6	Space Heating	>60	Puga - Union territory of India; Tapoban - West Bengal Parbati valley - Himachal Pradesh
7 8	Industrial use, soil warming	>40	Puga - Union territory of India; Tapoban - West Bengal Parbati valley - Himachal Pradesh
9	Aquaculture, agricul-ture, crocodile farming	<60	Low-enthalpy water needed in controlled conditions, found in: Manikaran, Tapoban, Parbati valley, North East Region; Anhoni-Samoni, Tatapani, Puga-Chumthang, Bakreshwar, Surajkund, and Unuguru.
10	Spa, swimming pools	>40	Low-enthalpy water from almost geothermal locations in India.
12	Industrial use, furniture, washing of metals	>50	Low- to medium-enthalpy water for small scale industries in West Coast, Cambay basin, Manikaran, Sohna Valley, Agnigundala, Manuguru.

drying vegetables, wheat and fruits instead of the unreliable (rainy, cold seasons and at night) traditional use of solar energy which can benefit farmers to a large extent. However, priority studies need to be carried out for the phase-wise development of geothermal energy in India. Figure 7 shows that the Himalayan belt together with the Son-Narmada lineament geothermal resources have potential for the biggest number of cascading uses.

4.2 Economical utilization, innovative uses and new exploration of geothermal energy in India

In order to kick start the use of geothermal energy, there is need to explore the options of using geothermal energy utilizing cheap and innovative technology. In this section, the local utilization of geothermal energy with innovative and economic technology is discussed.

- *Thermoelectric generators:* Use of thermoelectric generation technology is one of the start-up options to explore the possible use of geothermal. Thermoelectric power converters are compact, reliable and environmentally friendly innovative and cheap technology consisting of no moving parts, resulting in low or no maintenance. This technology is applicable to both high- and low-quality heat to generate electricity. Studies carried out at the China University of Geosciences, Beijing, revealed that power generators assembled with thermoelectric generator (TEG) modules had an installed power of 1 kW at a temperature difference of around 120°C and the generated power is directly proportional to the temperature difference between the hot and cold side (Changwei et al., 2014). The cost of direct heat to electricity (DHE) power generator is much lower in comparison to photovoltaics (PV) when equivalent energy is compared. The application of this technology may boost the use of geothermal energy in many far-flung areas of India.
- *Geothermal energy for brackish water desalination:* Many areas in India have an arid climate where access to portable water is still out of reach. However, these areas are blessed with underground brackish water along with geothermal resources. Brackish water desalination using geothermal energy can become one of the ways to provide water in these regions for drinking and irrigation purposes. The conventional method is capital intensive and regular operation and maintenance in remote areas present techno-economic problems. Effective integration of low-temperature geothermal energy resources along with the selection of an appropriate desalination technology and prioritized use could be the subject of one of the studies that needs to be carried out for the implementation of such a project in India.
- *Geothermal energy can be an added value to Indian farmers:* India has a bad reputation for its high rate of suicides among farmers with an annual average of 16,000 and peak values of 18,000 (Patel et al., 2012) mainly caused by socioeconomic factors. The cost of agriculture products depends on production and demand which is generally very low during the harvesting seasons. Therefore, on average, an Indian farmer does not receive the true value of his production, resulting in low returns and increasing debts. However, after the harvesting period, the same agricultural products (mostly tomatoes, potatoes, and other vegetable products) experience sky rocketing prices and then benefit mostly multinational companies who operate and own the cold storage units. Geothermal resources in India clearly provide the opportunity for the development of cold storage units with modern low-temperature technology which could be used by the farmers to increase the lifetime of their agriculture products and increase their value, reducing risk of suicides.
- *Assessment of geothermal potential in sedimentary areas:* Large parts of Indian are sedimentary basins with an area of about 3.17 million km^2, out of which only 19% have been explored for oil and gas. An extensive programme is proposed for geological and geophysical exploration studies of geothermal prospects conducted by oil and gas companies.
- *Assessment of geothermal potential using power density:* In order to estimate the resource capacity, power density, natural heat loss, and stored heat loss, numerical modelling is

commonly used (Benoit, 2013; Grant and Bixley, 2011). A robust resource estimate is generally conducted by more sophisticated tools like 3D numerical modelling incorporating well data. However, first order estimates, expressed in MW/km^2, are generally made in absence of data and models. The benefit of using these estimates is that they provide a value within reasonable limits without being time consuming like other methods. The power density increases with reservoir temperature and studies show that it varies between 8 MW/km^2 at 230°C and 30 MW/km^2 at 300°C (Grant, 2000). In the present case, considering the effective length of all geothermal provinces to be 700 km and the effective width to be 15 km with an average temperature of 80-90°C, and the power density of about 1 MW/km^2. The approximate resource estimate in terms of power will be around 9-10 GW.

5. PESTLE ANALYSIS FOR STRATEGIC DEVELOPMENT OF GEOTHERMAL ENERGY

This section refers to the book *Project strategy* published by Ingason and Jónasson in 2019. The impact of external factors on the development of geothermal energy in India has been identified using the well-known analysis tool - PESTLE - as shown in Figure 8.

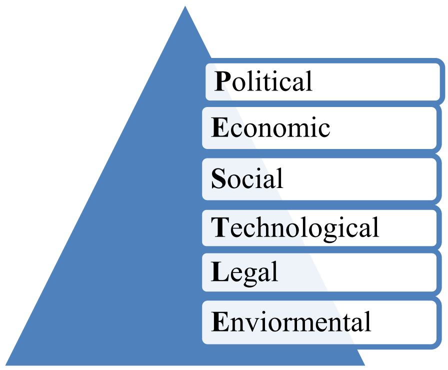


FIGURE 8: Impact of PESTLE factors for geothermal development in India

The individual aspects of the analysis are briefly presented below:

- *Political:* These factors are helpful in understanding the extent to which government may influence a certain sector or a business entity. Government jurisdictions, type of government and political stability can influence to a large extent the feasibility and viability of projects. Political factors may include tax policies, fiscal policy, trade tariffs, etc. which may significantly affect the business or economic environment.
- *Economic:* Factors like the tax system, interest rates, inflation rates, commodity prices, the employment rate, currency exchange rates, stock prices, etc., impact the economic performance of any organization, market or industry sector and have long term impact on the performance of the organization/industry or sector.
- *Social:* Social factors like age distribution, population growth rate, employment levels, religious beliefs, etc. have impacts on the strategic plan of a business entity when operating in varying circumstances with various dynamic social factors. An example of this can be social perception of hot springs as Avatar (miracle) of a God in India.
- *Technological:* Technological factors are related to technological innovations which may impact the operations of an industry sector or organization and can impact both favourably and unfavourably. Automation, security and reliability, communications, etc. are some of the factors that can influence the working of the organization or any operational industry sector.
- *Legal:* Legal factors are mostly based on policies and laws governing the local environment in which the organizations work or projects are executed and need to be mapped out for the formulation of strategies in accordance with the compliance, standards and regulations of that particular environment considering the associated risks and opportunities. Legal factors include but are not limited to safety standards, labour laws, consumer protection laws, etc., which affect the business performance due to maintaining certain policies or adhering to certain directives.
- *Environmental:* Factors which are influenced by the surroundings in which an organization or

project is proposed to be executed are termed environmental factors. Environmental factors have always been very critical for the energy sector. They include waste disposal, energy efficiency, climate change, soil erosion, etc.

The process of identification of these factors involves contributions from various disciplines, so that a clear picture of external factors can be built for the next stage of analysis. Many of these factors are impactful depending on their source. Only major potential factors, based on their ranking depending on their impact, have been considered for the current study. Development of geothermal energy has to face huge competition from other renewable sources of energy on the Indian market which have the benefit of easy accessibility and exploration along with low risk and easy funding. As discussed in the research methodology section, key potential issues have to be identified and categorized using the PESTLE technique analysing the implication of each factor. Based on their relative importance in current and future policies, the factors are categorized as "critical", "extensive", "important", "significant", "moderate", or "insignificant". The rate of likelihood of occurrence is described as "certainly", "extremely likely", "likely", "potential", "remotely possible", or "will not transpire" together with a brief consideration of impacts. The analysis will be helpful in understanding the consequences of various external factors and in making strategic decisions once each factor is fully researched.

5.1 PESTLE factors

The potential factors identified under each PESTLE category which have impact on the development of geothermal energy in India are (Table 3):

TABLE 3: Potential factors identified under PESTLE categories impacting on development of Geothermal energy

Political: Draft policy on geothermal energy in India Coordination of various stakeholders in governance Change in legislations or governance and government policies Funding, grants and initiatives Impact of regulators	*Economical:* Currency exchange risk General taxation issue
Social: Land acquisition and rehabilitation and resettlement (R&R) issue Frequent strikes by locals Frequent labour unrests in India	*Technological:* In efficient power infrastructure Risk in exploration stage Manufacturing
Legal: Current legislation on renewable energy sources of India	*Environment:* Multi stakeholders in environmental compliance process

The above tabulated factors are discussed briefly below considering their consequential impacts on the development of geothermal energy in India.

5.1.1 Political

India is considered one of the largest democracies in the world and is run by a federal system of governance. The agenda and ideology of ruling political parties or politicians govern policies and priorities of development thus impacts the business environment as a whole. In the given political scenario, the Government, both at national and state level have plans and are focused on providing "24×7 electric power for all" (Hon'ble Prime minister's speech).

Draft policy on geothermal energy in India

Following the XIIth Five Year Plan on non-conventional and renewable sources of energy by the Ministry of New and Renewable Energy (MNRE, 2019), the Government of India released policies for the strategic development of the renewable energy sector by framing the guidelines, regulatory mechanisms, and offering subsidies and tax benefits. In the case of geothermal energy, the Ministry of New and Renewable Energy (MNRE) has been supporting exploration activities and resource assessment during the last 25 years, including the formation of committees of highest level of decision consisting of policy makers and advisors to the Government. In 2012, the MNRE issued a draft policy on geothermal but it was not yet implemented in 2017. The Government of India has re-issued the draft policy in 2019. It contains the following aspects:

a. *Vision:* The vision of the geothermal policy is to make a substantial contribution to India's long-term energy supply and reduce our national greenhouse gas emissions by developing a sustainable, safe, secure, socially and environmentally responsible geothermal energy industry together with creating new employment opportunities and promoting environmentally sustainable energy production by installing 1,000 MWth and 20 MWe geothermal energy capacity in the initial phase till 2022 and 10,000 MWth and 1000 MWe by 2030.
b. *Goal:* Quoting the Prime Minister's vision on 24×7 - Power For all: "The Government is committed to bring about a transformative change in the power sector and ensure affordable 24×7 power for all homes, industrial and commercial establishments and adequate power for farms, in the next few years".
c. *Methodology:* The Government is planning to encourage demonstration projects at the first stage to assess the technical viability of the project before progressing to commercial projects.

A summary of the policy objectives which address the major constraints in geothermal energy development in India can be found in Appendix I.

After reviewing the draft policy and highlighting the major objectives above, the following measures are being suggested for the improvement of policy:

Bottom-up approach: According to the policy, most of the benefits will be allocated by the Central Government through State Nodal agencies, which will be designated by the State Governments. A direct mechanism connecting interested agencies/individuals with the Central Government should be established in order to avoid time consuming State-run nodal agencies. Simplifying official procedures will help entrepreneurs to realize ideas of localized use, provided they are being supported by policy. Use of geothermal energy for various purposes will attract people from diversified business entities, thus increasing investment into the sector.

Public awareness campaign: There is need to create awareness about the use of geothermal energy using different modes of communication. There are many un-reported hot springs which could be potential sites. Awareness among the public will act as tool for the identification of such potential sites. In addition to that, the use of geothermal energy as alternate, safe and modern energy needs to be promoted. Making geothermal energy an attractive source can be achieved using print media, video documentation and brochures. In many parts of India hot springs are associated with religious believe and the development of such fields will be challenging in terms of culture and values, therefore, well-addressed public awareness campaigns are crucial.

Infrastructure: The policy states that the state governments might consider the development of infrastructure. The construction of infrastructure or the offer of subsidy of an equivalent amount to the developer should, however, be made mandatory. It has been observed that infrastructure, which is being developed for a geothermal area, is later mostly utilized by state utilities. Most of potential geothermal sites in India are located far from capital cities and development of such fields requires the installation of major infrastructure like roads and essential supply lines for water and power. The costs can be considerable if sites are located in cut-off areas. Therefore, it is important for the state governments to subsidize infrastructure cost in order to ensure the feasibility of the project.

Power evacuation system and power purchase: One of the major challenges for the development of geothermal resources located in remote areas are evacuation infrastructure and grid integration. The developer has to provide for such infrastructure which has impact on the cost of the project. It has been proposed that cost of transmission should be provided for by the state governments and executed by DISCOM (Distribution Companies). The development of evacuation infrastructure and provision of measures for connectivity to the grid for renewable energy sources is considered the responsibility of the transmission utility. Regarding power purchase from geothermal energy resources, the Government has assured power sales of 25%. It is, however, recommended that power generated during the first 10 years or until the debt free stage is reached should be purchased by the local state governments to promote the use of renewable energy. A power purchase agreement supports the financial closure of the project.

Renewable purchase obligations: A mechanism needs to be implemented through policy intervention, which makes state electricity commissions necessary to purchase electricity from the renewable energy sources, in order to promote the energy mix from renewable sources.

Loan guarantee program (LGP): Geothermal projects are being considered risky in nature by the lenders/financers, therefore it is difficult to avail finances for the development of projects. In order to promote development of geothermal projects, it is proposed that an LGP should be part of the policy. A minimum of 75% of project cost after availing subsidy should be considered in an LGP for power projects. However, in case of direct use 100% financing through LGPs is proposed. Financial assurance is one of the major aspects for potential developers of geothermal projects.

Clearances and no-objection certificates (NOCs): Clearances have become one of the major hindrances for most developers and are considered one of the major threats/risks to project development because of the involvement of several other organizations, departments, and state and central agencies. It has been proposed to have a single window clearance for the project to attract investors from the private sector to participate in geothermal development.

Stage wise approach: A priority study based on the current data and inputs is needed for the phase wise development of geothermal energy production. Stage wise development needs to be incorporated in the policy to engage local stakeholders like local municipal bodies and district bodies.

Direct use promotion: Use of low-enthalpy geothermal energy for direct uses other than ground heat source pumps needs to be incorporated and promoted through the policy incentives.

Data base: The characteristics of selected geothermal fields need to be prepared in a way that interested developers or entrepreneurs can use the information as input for the assessment, modelling, monitoring and management of the geothermal resource.

Special Industrial Zones (SIZ): It has been proposed that Special Industrial Zones should be established to enhance growth of direct use from geothermal resources and generate local employment.

Building laws: The use of geothermal heat pumps for heating and cooling of residential and commercial spaces should be given priority in municipal building laws.

Fiscal incentives: The Government of India might consider fiscal incentives in the form of excise and customs duty reduction/exemption for renewable energy equipment.

Coordination of various stakeholders in governance

The energy sector of India is being steered by a complex network of various ministries as well as a planning commission, the National Institution for Transforming India (NITI Aayog) and regulatory bodies. Inputs for framing policy require consideration and comments from many other ministries like the Ministry of Environment, Forest and Climate Change, the Ministry of External Affairs, the Ministry of Urban Development, the Ministry of Water Resources, and the Department of Science and Technology. Once the policy is framed and floated, regulators both at central and state level come into the picture for the execution and monitoring of the policy. There is always a high degree of uncertainty for the investors and developers as the decision making for energy investments does not lie with the Central Government alone, but also with provincial governments across the whole country, which may or may not be part of the ruling Central Government.

The coordination among the different institution, ministries and between the Central and State Governments is slow and therefore one of the most challenging factors for the effective and efficient implementation of government initiatives. The current draft on geothermal energy development involves various stakeholders from different ministries which is a major challenge for effective development of geothermal resources.

Change in legislations or Governance and Government policies

For successful exploitation of the geothermal energy sector, Governments needs to provide legal and policy frameworks. Supportive policies and well-defined setup at all three levels of governance, i.e., at the national level, the state level and the intermediate/provincial level attract developers and investors. Well-functioning government institutions matter for business investment decisions and trust in them is a necessary ingredient to spur economic growth (Dasgupta, 2011; Algan and Cahuc, 2010).

The initiative for the development of geothermal energy was taken up by India in 2012 by floating a draft policy, based on which the Jammu and Kashmir State Power Development Corporation invited tenders from qualified bidders for the development of the Puga geothermal field for both electricity production and direct uses. The features of the policy attracted international bidders but the Government of India withdrew the policy before the letter of award was issued and the process was halted.

Among other factors, trust in the governance and finalization and implementation of policy has been one of the major setbacks for attracting developers and investors in geothermal energy development.

Funding, grants and initiatives

An initiative in form of promotion through grants and funding is one of the key requirements for the development of the energy sector. The cumulative growth of the installed capacity of solar energy as shown in Figure 9 highlights the role of the Jawaharlal Nehru National Solar Mission (JNNSM) scheme along with attractive funding and grants.

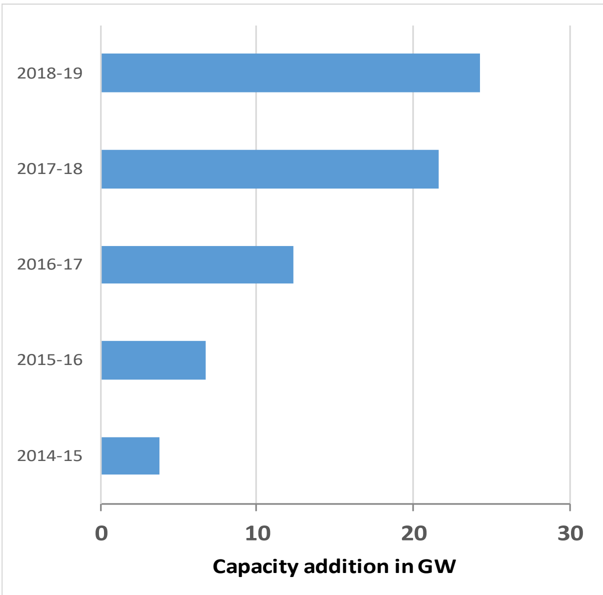


FIGURE 9: Cumulative growth of installed capacity of solar energy (MNRE, 2019)

The Government of India offers grants in total of Rs. 150,050 million (USD 1,969 million) in subsidy to promote solar capacity addition in the country. Initiatives had been launched providing about Rs. 900,000 million (USD 11,800 million) for developing solar energy using the bundling method with thermal power projects (Sharma, 2011). Through the revised draft policy, grants and funding have been assured through subsidy but there is no assurance for financing of debts. Current draft policy is based on power plant development while no specific institutional arrangement has been discussed for the development of geothermal energy. Increasing budgetary provisions for solar and other sources of renewable energy pose a challenge to the development of geothermal energy. A uniform approach in the development of all sectors of renewable energy is required for the development of geothermal energy in India.

Impact of regulators
The power generation and distribution across India prior to year 1990 was controlled and managed by state owned enterprises. Since the demand of energy has started to increase exponentially, investments from the private sector are needed because the public sector alone cannot cater the growing demand. In order to attract private investors, it is necessary to create a regulatory environment that minimizes unwanted political interference. Accordingly, the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERCs) were constituted at the central and state level, respectively, with the aim to ensure maintenance of service standards, tariff fixation, licensing, and promoting growth of the sector. These bodies were further strengthened by implementation of the Electricity Act in 2003. However, results and outcomes so far are not encouraging which signifies that political intervention hampers the growth of the energy sector. A review shows that the regulatory system in this sector lacks independence, accountability, transparency and stakeholder participation (Pradeep, 2009). The impact of regulatory mechanisms could be one of the political factors which affect the growth of geothermal energy in India.

5.1.2 Economical

India being one of the largest markets in the world is becoming an attractive destination for business owners. However, institutional deficiency together with changing market conditions and priorities of the Government are risks that can lead to economical melt down and can adversely hit business and hamper the growth or development of new sectors. Giving priority to development of geothermal energy in India can reduce risks for investors involved in investing in new sector.

Currency exchange risk
The currency exchange risk becomes an issue if a developer has revenue in one currency and payment of debt or part of the capital cost are in another currency. This is the case when renewable energy projects are developed and funded by foreign developers or through foreign investment (financing currency or hard currency). Revenue from the energy sales in the local market (revenue currency or local currency) are prone to the currency exchange risk. In order to avoid this scenario, developers prefer to make power purchase agreements (PPA) in hard cost, but it is common practice of distribution companies not to sign a PPA in hard cost. This reduces foreign investments in the energy market. A PPA is one of the mandatory requirements for the financial closure of a project. In case of geothermal power projects, financial closure becomes even more complicated due to associated risks and lenders reluctance to finance projects which involve currency exchange risks. Currency hedging is a common tool to avoid this risk. However, currency hedging is very expensive in India increasing the capital cost of the project.

General taxation issue
There has been significant change in tax systems across the world in the last twenty years. Changes of the tax policy in India are the result of several years of strategic development. Initially, tax policy was guided by a large number of demands placed on the Government (Bagchi and Nayak, 1994). Like other developing countries, India has gone through a significant change in the taxation regime over a period of time, but unfortunately studies on the impact on the economy due to those changes have never been carried out unlike in other developed countries (Auerbach and Slemrod, 1997). In the financial year 2017-18, the Government of India introduced a centralised tax system commonly known as Goods and Service Tax (GST). The tax structure came into effect in July 2017, after almost 17 years of deliberation and long delay, with the ultimate goal to stabilize and improve overall economic efficiency.

Almost two years after the implementation of the GST, there is a great deal of uncertainty about its net impact on the energy sector in India. According to the study released by the Council on Energy, Environment and Water (CEEW), and carried out by the International Institute for Sustainable Development, in 2019, implementation of GST has increased overall cost of energy projects and thus impacts the tariff parameter. The study also reveals that there have been huge uncertainties in the calculation of taxes on various components of projects. Therefore, taxation has been slowing done growth of the energy sector in the last two years. Uncertainty along with policy shocks (e.g. imposition of a safeguard duty of 25% on imported solar panels) shrinks the renewable energy sector in India which also shows in data from the Ministry of New and Renewable Energy. The data show that out of 175 GW planned to be produced from renewable energy by 2022, only 73.35 GW had been installed by 2019,

All such changes in the tax regime are non-creditable for renewable energy players. Therefore, changes in taxation and its associated uncertainties are some of the key economic factors for projects, which are unique and new to the market.

5.1.3 Social

India being one of the oldest civilizations is a country of diversities and cultures where people of many ethnic groups have lived together for centuries. There are about 1650 spoken languages and dialects. Impacts of the introduction of any new product to India needs to be studied well. The study of sociological factors helps understanding and strategizing events that affect the market and community.

Land acquisition and rehabilitation and resettlement (R&R) issues
India is an agrarian economy with almost 72.2 % of the population living in rural areas (Census Data from 2001) and depending on agriculture for their income. In the past decade, the Government of India together with private developers has invested into the infrastructure sector which is considered a key factor for propelling economic growth. Attractive governmental policies concerning infrastructure invited vast amounts of foreign direct investment into the country. However, the sector has been facing lot of uncertainties due to land acquisition and R&R issues.

A recent report submitted to the Parliament in December 2018 states that more than 435 infrastructure projects have been delayed mainly due to land acquisition and R&R issues which included but are not limited to energy generating projects. The major reasons for delays are attributed to delays in obtaining possession of the land acquired and rehabilitation and resettlement of affected families by the government. After identifying a major constraint, the Government of India replaced a 120 years old colonial statute, the Land Acquisition Act 1894, by the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act (LARR Act), 2013, which took effect on 01.01.2014. However, it has been reported that many difficulties are being faced in the implementation of the act (Press Information Bureau, Ministry of Rural Development) and amendments were suggested by the Department of Land Resources (DoLR). The act was drafted with the goal to encourage participative management of the people whose land is being acquired or who are being displaced, ending the forced acquisition of land by the government authorities. However, higher compensation along with the agreed compensation amount and return of unused land etc., under the LARR act increased the land cost of projects, thus increasing the overall cost. The uncertainties/risks due to land acquisition and R&R issues can be a critical roadblock to the development of geothermal projects, particularly where acquisition of private land and displacement of families are required.

Frequent strikes by locals
The Periodic Labour Force Survey (PLFS) report of the National Sample Survey Office (NSSO) shows that unemployment rate in India was 6% during the financial year 2017-18 Which is envisaged to increase in case of a meltdown of the Indian economy. A long-standing economic rule of thumb, often referred to as Okun’s Law, suggests that increased economic growth generally leads to increased employment, and vice versa. Unfortunately, many job seekers in India do not have access to specialized training centres to develop skills, thus reducing their potential.

Engineering projects and energy projects in particular need a specialized skilled workforce for the execution of the projects what limits the use of the local population and leads to protests and frequent strikes by the locals on the project sites. It is part of general practice of contracts in India that delays on account of the local population have to be compensated by the owner which increases the cost of the project and thus impacts the tariff of energy and its competitiveness on the energy market. Employment of local population regulatory mechanisms, which have not been framed so far, are also considered one of the major threats to project development, considering the growing unemployment rate in India.

Frequent labour unrests in India
The major factors that lead to dispute or friction between the industry and the labourers revolve around factors of employment, non-employment, terms of contact, conditions of labour and non-compliance of regulation. Some of these issues pose challenges that need immediate attention to prevent exploitation and to achieve social justice and equitable economic growth as urged by the ILO Declaration in 2008. Health hazards due to poor hygienic conditions, non-compliance to regulations and standards along with political factors are some of the causes for labour unrests in India. A study of labour conflicts and foreign investments in India concluded that foreign direct investment tends to avoid states that have high incidences of labour conflicts, i.e., the number of man-days lost due to work stoppages (Menon and Sanyal, 2004). Labour laws have been enacted in order to safeguard the interests of workers. However, it is commonly agreed on, that these laws are too complex to adhere with, thus create an opportunity for companies to circumvent the protective laws and therefore, the percentage of workers actually protected by the legislations is small and large parts of the workers are exposed unprotected.

5.1.4 Technological

Renewable energy generation is always connected with technology. Cost optimization is one of the key requirements for promoting the use of renewable energy. Use of new and innovative technologies are the factors that can help making energy accessible and economic to end users.

Inefficient power infrastructure
Power infrastructure is one of the most challenging problems for the generation and distribution sector in India and is one of the reasons for slow growth of economic activities associated with the energy sector. The outdated electricity grid connection system is considered one of the key factors causing major losses, frequent outages and non-availability of construction power along with power evacuation.

The construction power that is being supplied through diesel generators due to non-availability of a transmission network increases the project cost and risks associated and there are instances when projects were commissioned without a power evacuation arrangement in place (9 MW Dah and Hanu and 45 MW Chutak HEP in Jammu and Kashmir state). Investments in the grid need to be in sync with the generation. Significant investments are required to augment the capacity as well as to replace the outdated infrastructure to fulfil present and future needs. Due to AT&C losses and operational inefficiencies, financial health of distribution companies is currently affected by humongous out-standing debts towards the generating companies, what in turn disturbs the cash flow of generating companies and impacts the development of new projects. Development of infrastructure for power evacuation from power surplus to power deficient areas could be one of the major game changers for the development of the renewable energy sector. While there is urgent need to ramp up the building of infrastructure in the transmission sector, digitalization of the grid is equally important. The increase in efficiency in the power infrastructure through technological interventions will attract developers to invest in the energy sector. Geothermal projects, often located in remote areas, are prone to the above-mentioned factors and their impact may decrease private sector participation and foreign investment.

Stabilization of the grid will increase the investment in India and reduces India's excessive reliance on fossil fuel imports (Shah and Buckley, 2019). A robust grid network is crucial to minimize grid curtailments for renewable power and ensuring that renewable assets do not face the financial risk of asset stranding like the Indian thermal power sector.

Lack of technical competence

In addition to material and machines, manpower is one of the key resources for the development. Geothermal development requires manpower with expertise in various disciplines. The core competence areas are applied science, engineering and management, such as geology, geophysics, geochemistry, reservoir engineering, environmental science, project management and geothermal engineering. India does not have a dedicated geothermal development excellence centre, which would impart training in various fields involved in geothermal development. Very few qualified geothermal trained professionals are currently in India, considering the geothermal potential. Therefore, one of the challenges for the developers is engaging professionals from other countries which has an impact on the project cost. A capacity development programme could be one of the measures to avoid the impact by signing MoUs for knowledge transfer with leading capacity development programme countries like Iceland, New Zealand, Germany, USA and Turkey. Data from various geothermal fields need to be systematically arranged and made accessible to developers and investors to allow proper planning.

Manufacturing

Import of machines and equipment from foreign countries and associated taxes and duties increase the capital cost of projects. To reduce manufacturing cost and thereby reducing the cost of geothermal projects, India needs to consider revamping and upgrading research and development in geothermal energy sector. This can be achieved by supporting core domestic companies through industrial benefit policies to produce the required machinery and equipment. An initiative in this sector would enable a substantial reduction of the cost of geothermal technology.

Risk during exploration stage

Since India is in the initial or take-off stage of geothermal energy development, it needs to go through a stage wise process. The risks and uncertainties are high in the beginning. Surface exploration technology has progressed a lot, but cannot accurately establish the depth of the reservoir or the exact steam output from potential wells. Production wells are only considered, after exploration drilling has provided values for some important parameters. The exploration challenges of geothermal energy development are similar to those in the oil and gas industry where the exploration risk is also very high. India has little capacity in drilling technology and most of the drilling jobs are carried by the Oil and Natural Gas Company (ONGC) for the exploration of oil and natural gas sector. For the purpose of drilling in geothermal areas, there is no independent institutional arrangement whose services could be utilized for the purpose of drilling. Interested developers (public or private sector) need to rely on foreign drilling companies which may increase the capital cost of the project. The non-availability of desired technology in the local market can hamper the growth of geothermal development and can lead to over-sizing of the potential geothermal plant.

5.1.5 Legal

Factors like policies, laws and compliance to laws that can affect an industry/organization are analysed with their impact, so that a strategic decision can be taken. Included are safety standards, labour laws, consumer protection laws, etc., that affect the execution of projects.

Current legislation on renewable energy sources of India

With increase in energy demand mainly due to growth in population, urbanization and industrialization, India is facing energy shortage in various sectors and the energy demand is met by thermal sources in the energy mix. India commissioned the production of 9626 MW during the financial year 2018-19 out of which 85% came from thermal power plants, 9.5% from the hydro sector and 5.5% from nuclear power plants accompanied by the production of immense amounts of greenhouse gases (CEA, 2019b). To keep up with the future energy demand, the current setup of energy exploitation and transmission needs to be transformed profoundly. This transformation started in the year 2000 through incorporation of policies which have played a vital role in the development of the energy sector.

India's population is almost 1.339 billion, distributed into 28 states and 9 union territories. Policies in India are either national or state policies depending on the issuing and regulating authority. A national policy is approved and issued by the Central Government and benefits of national policy can be extended to all states with or without exceptions. There are almost 55 policies issued by the Central Government or state governments for the development of renewable energy. The brief list of major national policies giving information on the following parameters can be found in Appendix II. They include:

- Type of policy;
- Target sector; and
- Major benefits.

In order to provide a timeline of national policies, a statistical tool from the International Energy Agency / International Renewable Energy Agency (IEA/ IREA) was applied using the following main policies as inputs (Figure 10):

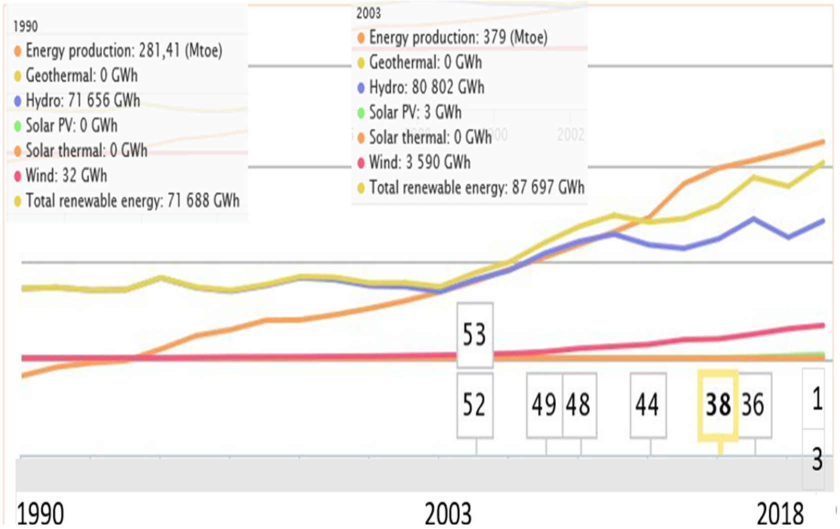


FIGURE 10: National policies, timeline and impact

- The Electricity Act. 2003 (Policy code: 53);
- Government Assistance for Renewable Energy Project (Wind, Solar, Biofuel, Hydro) (Policy code: 52));
- National Electricity Policy (Policy code: 49);
- Tariff policy 2006 (Policy code: 48);
- Solar and Wind Power Generation Mission based Incentives (Policy code: 44);
- Jawaharlal Nehru National Solar Mission (Phase I, II, III) (Policy code: 38);
- Renewable Energy Certificate System (Policy code: 36);
- National Wind-Solar Hybrid policy,2018 (Policy code: 03);
- Capital Grants for Off-Grid and Decentralized Concentrated Solar Thermal (CST) Technologies for Community Cooking, Process Heat and Space Heating & Cooling Applications – Extension (Policy code: 01).

Figure 10 shows that there has been a lot of transformational progressive change in energy production from year 2003 onwards in comparison to 1990-2000. The effective implementation directives through policies have encouraged the developers to increase the share of renewable energy. However, deliberations on critical aspects of policy and regulatory interventions and their long-term sustainable implications will help taking informed decisions and contribute to the development of the energy sector and in particular the renewable share. Figure 8 shows that wind and solar energy development increases after policy interventions. The installed capacity of solar energy increase from a cumulative capacity of 12.28 GW in 2015-16 to 24.33 GW in 2018-19 clearly signifies that proper integration of policy interventions holds the key to sustainable development goals. However, lack of growth in case of geothermal energy can easily be attributed to the absence of clear policy, a legal framework and regulatory mechanisms. This is status, despite the fact that geothermal prospects in India have been known for more than 25-30 years and a variety of surface studies along with shallow exploratory drilling have been carried out. The Government of India has recognized that it is very important to take a supporting role in the development of geothermal energy by drafting a national policy on geothermal energy along with a legal framework which was issued in 2015. However, the policy was withdrawn shortly after its issuance but was floated in September 2019 with the request to get comments from stakeholders.

5.1.6 Environment

Exploration and development of renewable sources of energy of any form impacts the surrounding environment. Environmental factors are certainly critical for the energy sector. Environmental factors which need to be considered include climate, weather, geographical location, global climate changes, environmental offsets, etc.

Multi stakeholders in environmental compliance process
New initiatives for the energy mix along with varying policies concerning climate change create opportunities for accelerating the investment in renewable energy sources with applicable guidelines for environmental protection measures. However, the process of issuing clearance is still in progress and violation of environmental clearances (EC) have been brought before the Government by the Controller Auditor General of India (CAG, 2017). The CAG pointed out that out of 216 projects only in 14% the terms of reference were granted within the prescribed time limit of 60 days, in other projects there were delays of up to a year. In 11% of the cases, the environmental clearance was granted within the prescribed time limit of 105 days (CAG, 2017). The delay in issuance of the EC leads to an initial delay of projects and thus impacts financial viability of the projects by increasing cost due to change in price indices of various key resources. The reason for a delay in the issuance of environmental clearance is mainly the involvement of both state and Central Government Agencies, which in turn depend on various state utilities, making it a complex web of various organizations. Lack of transparency and uncertainties in the process of issuance of EC is one of the major challenges in the development of infrastructure and energy projects in India.

Slow processing of environmental clearances hinders development of geothermal resources in India. A draft policy for a centralization of the environmental clearance might improve this situation, creating a more attractive scenario for investors and developers.

5.2 Stakeholder mapping using PESTLE factors

Based on the various PESTLE factors, stakeholders who play a major role in the development of geothermal energy in India are listed in Table 4. Knowledge of relevant stakeholders with regards to geothermal energy can be adapted generally, based on the renewable energy sector along with oil and gas sector as an additional reference. An overview based on PESTLE factors is helpful to identify and map the involvement of different stakeholders in geothermal energy development in India (Table 4). This map highlights all the relevant stakeholders and their influence on the six PESTLE sectors that constitute geothermal energy in India. It allows the identification of the extent of the stakeholder roles within the PESTLE framework.

From the political, economic, social, technology, legal and environmental aspects of the analysis, it is evident that the development of public policy for geothermal energy development in India requires a close collaboration between the central and regional governments along with all ministries and regulatory bodies.

TABLE 4: List of major stakeholders based on PESTEL framework

Stakeholder	Sym-bol	P	Ec	S	T	L	Ev
Ministries							
Department of Agriculture and Cooperation	A1		✓	✓			
Department of Agricultural Research and Education	A2			✓			✓
Ministry of Power	A3	✓	✓		✓		✓
Ministry of Culture	A4			✓			
Ministry of Environment, Forests & Climate Change	A5	✓		✓			✓
Ministry of Earth Sciences (MoES)	A6				✓		✓
Ministry of Food Processing Industries (MOFPI)	A7		✓		✓		
Ministry of Human Resource Development (MHRD)	A8				✓		
Ministry of Labour	A9	✓		✓		✓	
Ministry of Law and Justice	A10	✓		✓		✓	
Ministry of Tourism	A11	✓	✓				✓
Ministry of Rural Development	A12			✓		✓	
Ministry of New and Renewable energy	A13	✓	✓		✓		✓
Apex/Independent Offices/Commissions							
Planning Commission (NITI Ayoug)	B1	✓	✓	✓	✓	✓	
Central Electricity Authority	B2	✓	✓		✓		
Central Vigilance Commission (CVC)	B3	✓					
Centre Electricity Regulatory Commission	B4		✓	✓	✓		
State Electricity Regulatory Commission	B5		✓	✓	✓		
Judiciary							
Supreme Court	B6			✓		✓	
State High Court	B7			✓		✓	
Other Institutions/ governments/organizations							
National banks	C1		✓		✓		
State governments	C2	✓		✓			✓
NGOs	C3	✓					✓
Public	C4			✓			

P: Political; Ec: Economical; S: Social; T: Technological; L: Legal; and Ev: Environmental

5.3 Power/influence matrix for identifying major stakeholders

Based on the list of stakeholders involved within the PESTEL framework, a power/influence matrix (Figure 11) has been used to identify and categorize project stakeholders by the power and influence they have on the development of geothermal power projects in India. From a power/interest grid, key stakeholders with high power and high interest have been identified. It provides information which helps to prioritize stakeholders. Stakeholders located in quadrant IV (Manage closely) are major stakeholders with the roles and responsibilities shown in Table 5.

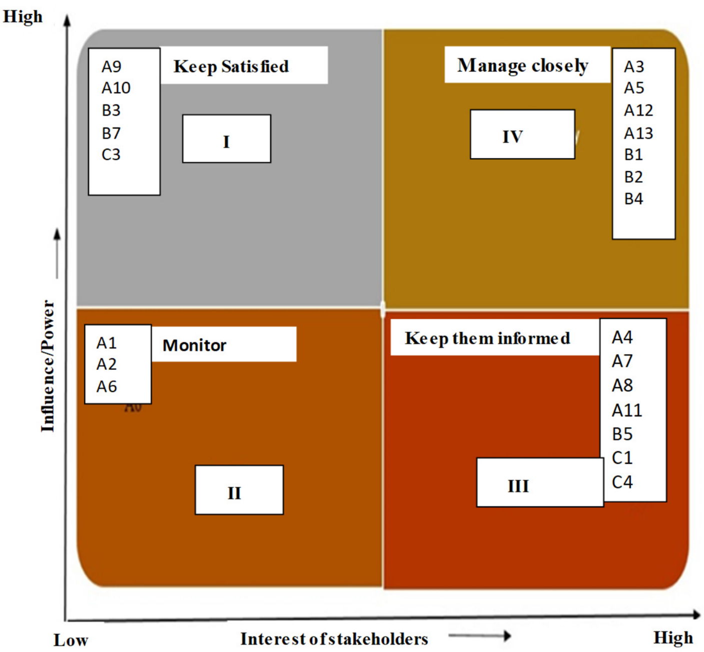


FIGURE 11: Power influence matrix

TABLE 5: Roles and responsibilities of major stakeholders

Symbol	Name of stakeholder	Brief role and responsibilities
A3	Ministry of Power	Ministry of Power (MoP, 2019): General policy making in the electric power sector and dealing with issues relating to energy policy and coordination thereof. Research, development and technical assistance relating to hydro-electric and thermal power, transmission system network and distribution systems in the states/UTs. Administration of the Electricity Act, 2003. All matters concerning energy conservation and energy efficiency pertaining to the power sector.
A5	Ministry of Environment, Forests & Climate Change	Ministry of Envir., Forest and Climate Change (MoEF&CC, 2019): The nodal agency in the administrative structure of the Central Government for planning, promotion, co-ordination and overseeing the implementation of India's environmental and forestry policies and programmes. Primary concerns are implementation of policies and programmes relating to conservation of natural resources including its lakes and rivers, its biodiversity, forests and wildlife, ensuring the welfare of animals, and prevention and abatement of pollution.
A12	Ministry of Rural Development	Ministry of Rural Development (MoRD, 2019): Pivotal role in the overall development strategy of the country. Consists of two Departments: (i) Department of Rural Development; and (ii) Department of Land Resources. The main tasks of the Ministry are: Providing livelihood opportunities to those in need including women and other vulnerable groups with focus on Below Poverty Line (BPL) households. Providing for the enhancement of livelihood security of households in rural areas by providing at least 100 days of guaranteed wage employment in every financial year to every household demanding it. Provision of all-weather rural connectivity to unconnected rural habitations and upgradation of existing roads to provide market access
A13	Ministry of New and Renewable Energy	Ministry of New and Renewable Energy (MNRE, 2019): Nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy sources to supplement the energy requirements of the country
B1	Planning Commission (NITI Aayog)	Planning Commission (NITI, 2019): Primarily formulates policy. The different ministries of the Central Government prepare projects based on these policies. Supports a cooperative federal structure where the centre and the states prepare development policies together. Provides direction to monitoring and evaluation activities in India. Also pegs importance to the quality standards, ethical procedures and provides appropriate institutional mechanisms. It is a central administrative body of India with domain in all fields of economy.

Symbol	Name of stakeholder	Brief role and responsibilities
B2	Central Electricity Authority	Central Electricity Authority (CEA, 2019c): Formulates National Electricity Plan every five years for optimum utilization of available resources for power generation. Establishes technical standards and creates data base for power sector by registering all generating units of 0.5 MW and above. Promotes R&D and state-of-art technology in the power sector. Complies with provisions of the Electricity Act, 2003.
B4	Centre Electricity Regulatory Commission	Centre Electricity Regulatory Commission (CERC, 2019): Mandatory functions: To regulate the tariff of generating companies owned or controlled by the Central Government; To regulate the tariff of generating companies other than those owned or controlled by the Central Government if such generating companies enter into or otherwise have a composite scheme for generation and sale of electricity in more than one state; To regulate the inter-state transmission of electricity; To determine tariff for inter-state transmission of electricity; To issue licences to persons to function as transmission licensee and electricity trader with respect to the inter-state operations; To improve access to information for all stakeholders; To adjudicate upon disputes involving generating companies or transmission licenses with regard to matters connected with clauses (a) to (d) above and to refer any dispute for arbitration. Advisory functions are: Formulation of national electricity policy and tariff policy; Promotion of competition, efficiency and economy in the activities of the electricity industry; Promotion of investment in electricity industry; Any other matter referred to the Central Commission by the Central Government.

5.4 Analysis of results from PESTLE

The political, economic, social, technological, legal and environmental barriers for the development of geothermal energy in India have been identified. Based on the PESTLE factors, stakeholders were mapped in order to identify ministries, public institutions and various other bodies. A power influence matrix analysis was carried out to identify the extent of the role of stakeholders with high interest and high influence on the development of the geothermal sector in India. Considering the role of stakeholders in quadrant IV in Figure 11, following key areas need to be addressed in order successfully implement the geothermal sector in India:

1. Policy
2. Regulatory
3. Fiscal incentives and financing
4. Manufacturing
5. Transmission requirements
6. Priority study of most promising locations

5.4.1 Policy

The Government of India (GoI) through the Ministry of Power (MoP) formulates/revises policies or action plans for the development of the geothermal energy sector in consultation with State Governments encompassing all key aspects for development of the sector. The GoI has fixed no timeframe for implementation of the policy in order to speed up the development. The GoI must speed-up this task and ensure that the desired law be enacted expeditiously.

The Central Electricity Regulatory Commission (TERC) should address the use of geothermal energy in the current tariff determination policy in order to ensure that states adopt this provision in their regulatory framework. In addition, uncertainties in policy and regulatory matters must be removed by the state governments and Central Government. In order to expedite the development of the geothermal energy sector, special purpose vehicles (SPV) may be set by each state in consultation with NITI Aayog (Planning Commission), so that all initial time consuming and risky tasks, such as acquisition of land, obtaining clearances, preparation of DPRs, tying up of basic facilities can be carried out by the SPV before handing over the project to the developer.

There is urgent need of incorporating laws in various other sectors like agriculture, fisheries, horticulture, food and dairies for promoting the use of geothermal energy based on site specific conditions and for stronger initiatives at local level (municipalities) for the promotion of geothermal energy.

5.4.2 Regulatory

As discussed earlier in this report, only 16 out of 32 states and 7 UTs have adopted the Renewable Purchase Obligation (RPO). All states must be mandated to have an energy mix containing renewable energy sources in a well-defined time frame. There is an urgent need for clarity on the RPO framework. Further, there should be no cap on renewable energies and states with maximum percentage should be rewarded.

SERCs must monitor the compliance of renewable energy obligations through the ARR/tariff approval process. Further, SERCs must consider monitoring compliance with the RPO, depending on availability of energy from renewable sources.

A number of states (such as Maharashtra, Gujarat, Madhya Pradesh and Karnataka) do not allow the procurement of renewable energy power from outside the state. This puts an artificial barrier on renewable energy power generation and investments. Instead, regulators can identify ways and means of selling this power to neighbouring states which are short on renewable energy resources or RPO at a mutually agreed rate.

Fixation of tariff should be worked out, based on direct uses of geothermal energy in various fields. But in case of power generation, transmission of geothermal power based on the concession must be limited to be within the state.

5.4.3 Fiscal incentives and financing

The GoI may consider fiscal incentives in form of excise and customs duty reduction/exemption for equipment being used by the developers as was done in the case of the hydropower sector. Change in law and associated financial risks should be covered by fiscal incentives.

Geothermal energy is considered risky due to uncertainty in resource properties and therefore does not attract project investors or lenders. In order to increase the availability of funds, a Loan Guaranteed Programme (LGP) for geothermal projects needs to be assured through a policy intervention by the Ministry of Finance. A minimum of 75% of the project cost after availing subsidy should be considered in the LGP for power projects and, in case of direct use, 100% finances through an LGP is proposed. However, options for increasing availability of funds need to be exercised. The GoI might consider mandating insurance companies as well as state and central provident funds to invest a proportion of their portfolio into development of the geothermal energy sector. Investments of such type make sense for business entities like insurances, as geothermal energy will reduce the risk related to environment and energy access resulting in less insurance pay outs.

In order to fast track development of geothermal energy, the GoI should declare geothermal a priority sector. At present, the priority sectors broadly comprise agriculture, small-scale industries and other activities/borrowers (such as small business, retail trade, small transport operators, professional and self-employed persons, housing, education loans, microcredit etc.). This inclusion would increase the financing options and large financial institutions would participate in the financing.

The GoI might consider to allow a higher exemption on the rate of interest of home loans under income tax rebates for individuals who install geothermal energy applications in their homes. Once again, the extent of rebate could vary depending on the number of applications installed or the type of installations installed and site-specific conditions.

5.4.4 Manufacturing

In order to reduce the capital cost of projects, the GoI needs to revamp and upgrade its geothermal research and development capabilities as well as domestic manufacturing capabilities. This can be achieved by building in-house capacities through institutional arrangements and international collaborations and by promoting core companies in exploration and drilling. This will reduce the capital cost of projects. The Ministry of Industries and Commerce can play a significant role by floating a manufacture friendly policy.

5.4.5 Transmission requirement

The mandate of grid connectivity and power evacuation from geothermal power plants should be borne by state transmission utilities (STUs) or distribution companies (DISCOMs) through capital (CAPEX) plans. However, STUs or DISCOMs need to provide funds for this purpose. An accountability mechanism like in Himachal Pardesh needs to framed which makes STUs accountable for placing evacuation arrangements well before the commissioning of projects. This objective can easily be achieved through state run state electricity regulatory commissions which are being headed by the Central Electricity Regulatory Commission.

5.4.6 Priority study of most promising locations

A priority study based on available data on resource properties needs to be carried out for the step wise development of geothermal fields. Micro-mapping of geothermal direct uses needs to be carried out through state nodal agencies. A plan for the development of projects indicating benefits envisaged, quantum of beneficiaries, and location in each potential district needs to be laid out. Less challenging locations with low risk and high potential need to be developed first to avoid setbacks to the industry during the initial phase.

6. FINANCIAL MODEL FOR GEOTHERMAL ENERGY PARK AT PUGA, LADAKH

The Puga geothermal field is found in the northwest part of the Himalayas in the Ladakh region in the Jammu and Kashmir state. It is located about 4400 m above sea level about 190 km from Leh city and 700 km from the summer capital Srinagar. Surrounded by hills, the place is a key destination for tourists enjoying nature, adventure, culture, and spirituality. According to the reports of the Ministry of Tourism, 327 000 tourists, including 49,500 foreigners, visited Leh in 2018.

Based on geological, geophysical, geochemistry, and hydrological studies and considering climatic conditions, a feasibility study for the development of a binary power plant in the low-temperature geothermal field in Puga was carried out. The result was that isopentane as working fluid would give the highest net power output of approximately 15 MW and that the source has a reasonable district heating capacity at a reinjection temperature of 73°C (Ahangar, 2012). The study could not resolve whether the project is technical or financially feasible considering the current energy market. In the following, the financial viability of the project is assessed which includes the following:

1. 15 MW power plant;
2. Geothermal spa;
3. District heating; and
4. Greenhouse.

In absence of regulations for tariff calculation for geothermal energy, the factors considered are in accordance with the regulation from Central Electricity Regulatory Commission Renewable Energy Tariff Order 2019-20 (CERC, 2017) for the calculation of tariff for small hydro power plants with a capacity of up to 25 MW. Following factors have been considered for the calculation of the tariff (Table 5):

TABLE 5: Factors considered for calculation of tariff from a small geothermal plant

Cost per MW:	Rs. 160×10^6 / MW*	Debt equity ratio:	70:30
Cost of land:	0 (state land)	Rate of interest:	10.25%
Discounting factor:	10.62%	Rate of return on equity:	14%
O&M expenses:	1.50%	Spares escalation:	6%
Annual increase in O&M expenses:	2%	Interest on working capital:	13.50%
Plant load factor:	75%*	Lifetime of project:	20 years**

* IRENA (2019); ** CERC (2019)

The levelized tariff for 35 years and levelized tariff for 12 years have been calculated for the following two scenarios; S-I: With all draft policy benefits; and S-II: without any policy benefits (Table 6):

TABLE 6: Levelized tariffs for 35 years and 12 years, with all draft policy benefits; and without them

Scenario	Capital cost (Million Rs.)	Tariff for 12 years (Rs.)	Levelized tariff for 35 years (Rs./US cents)	Calculation
S-I: With all draft policy benefits	1,680	3.59	2.80	Appendix III: Table 1
S-II: Without draft policy benefits	2,400	5.13	4.16	Appendix III: Table 2

In case of scenario S-I, the tariff of the project is within the saleable range of around Rs 3.20 per unit of power purchased by the J&K state. However, the cost of transmission is excluded from capital cost of the project. If the cost of transmission (10×10^6 Rs./km for a distance of 38 km) is loaded on the capital cost for the S-I scenario, the cost of electricity is Rs 4.16 and Rs 3.24 for 12 and 35 years, respectively (Scenario III, Appendix III, Table 3).

In order to make the project more attractive an energy park is proposed, which includes a geothermal Spa, district heating and a greenhouse. A spa would make the area even more attractive to tourists. There are many success stories (like the Blue Lagoon in Iceland) where the revenue generated from the spa or other direct uses is higher than the revenue generated from the sale of electricity. The quantification of these externalities and revenue benefits can change the financial viability of projects in places where the tourism industry is well established.

7. DISCUSSION AND CONCLUSIONS

The demand for energy in India is likely to increase manifold and will probably be met by fossil fuels, thereby increasing CO_2 world footprint from 7% today to 14% by 2040. Considering its international commitment, India is exploring new opportunities to meet the energy need utilizing renewable sources of energy. Regarding the geothermal potential of India, possibilities for use of this renewable and sustainable source of energy were being studied keeping in mind the current legislation and other factors.

The Lindal diagram shows that geothermal energy in India looks best suited for various direct applications like furniture industry, industrial use, space heating, food processing, green houses, refrigeration, food drying and aquaculture, etc. along with ideally electricity generation in areas like Puga, Tatapani, Tapoban and Manikaran. The use of geothermal energy can increase socio-economic activities and reduce the risk of farmer suicide. The resource capacity is estimated to be in the range 1-10 GWe. Considering an effective area of 10,500 km^2, the energy density within the area, 1 MW/km^2 is fairly low.

This study also identified the impact of various factors using PESTLE analysis. This analysis allows the identification of major stakeholders with power and influence on the development of the geothermal sector in India. A clear picture emerges regarding areas of the environment and circumstances the stakeholders are operating in, identifying impactful factors that need close monitoring. The identification of relevant stakeholders in the geothermal energy sector will improve policies for geothermal energy development by supporting policy makers to formulate or incorporate draft policy on geothermal development. A detailed analysis of the political, economic, social, technology, legal and environmental factors and stakeholders shows that the development of public policy for geothermal development in India requires a close collaboration between the Central Government and regional governments.

This finding underlines the need to design appropriate policies that focus on domains like policy, regulation, fiscal incentives, financing, transmission requirement and manufacturing, together with exploration studies for the most promising areas for strategic development of geothermal energy in India.

A financial model was developed for a geothermal energy park applying current draft policy benefits. It shows the financial viability of a technically feasible project in Puga, Leh, in the state of Jammu and Kashmir.

Exploration and development of geothermal energy is a major task for India and stagnation in development of geothermal resources is mainly due to absence of policy supporting the developers.

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APPENDIX I: Highlights of current geothermal legislation

Authority/Ownership of geothermal resources: Policy considers geothermal resources/prospects national resources, as is the case with hydrocarbons. State guidelines may however be followed when providing relevant approvals/licenses for exploration and mining. The land owner has no right to explore or exploit the geothermal resource though the land owner has the right to exploit shallow ground water. The State Governments are obliged to educate the people about the hot springs which are associated with religious faith of locals.

Prospecting and exploration license: A procedural mechanism has been formulated for:
- (i) Evaluation of the proposal;
- (ii) Identification of single/multiple parties for grant of license;
- (iii) Progress review; and
- (iv) Evaluation of the final report and recommendations for further work.

Proper mechanism has been framed for interactions between the state government and Central Government with fixed timelines in respect of projects. A procedure for a selection of an agency for prospecting, exploration and electricity generation has also been framed.

Mandatory clearances: A well-defined comprehensive list of the mandatory clearances needed is furnished in the policy documents, which includes but is not limited to
- (i) Environmental clearance; and
- (ii) Permission from the State Government, etc.

Prospecting and exploration: In this part of the guidelines, it is entrusted to various investigation bodies to re-draw the geothermal map of India based on chemical composition and lithology/geological parameters from an average depth of 100 m. It has been proposed to divide the process into two stages. For phase I (exploration and resource estimation), The Government of India has proposed to provide for up to 50% of the deep drilling exploration cost, based on the results of exploration, assuming it is completed to a special level. In phase II (plant setup and power production), it has been proposed in the draft policy for projects under research and development that 30% of the cost should be supported through a financial grant from the Central/state government, including the cost of land and licenses for installation of the power plant. For industrial power plants, however, 30% of the capital cost or Rs. 90 million/MW, whichever is less, should be offered as subsidy for the development of the power project. Methodology for reconnaissance surveys and specifications for land leases have also been proposed in the draft policy. There has been set a limit for exploration of not more than 100 km^2.

Assessment of geothermal energy potential and preparation of DPR: Formulated in the draft policy, is a list of all necessary fields which need to be incorporated when carrying out the assessment of the total geothermal energy potential. The assessment can be split into two parts, total energy and recoverable energy. The recoverable energy could be in form of electricity and other industrial uses, such as heating, cooling, and food processing.

Power production: The applicant/agency which has already completed prospecting/exploration of a particular geothermal area should be given priority for the development and power production. A complete plan including the production layout may be submitted. The plan should assume an average life of 20 years for the production machinery/project. The MNRE has also proposed to consider the following major incentives/exemptions/grants during this stage:

1) Geothermal energy may be declared a priority for energy development;
2) The incentives for geothermal energy development may be granted at par with solar energy;
3) The MNRE may provide subsidy/financial support for up to 50% of the cost of the exploration (deep drilling) and once the reservoir is established, a 30% grant will be given on the remaining amount for commercial power production;

4) Soft loans may be made available at concessional interest rates as is applicable in other RE technologies through the Indian Renewable Energy Development Agency (IREDA) for supporting exploration activity;
5) The import of machinery and equipment for exploration and power production may be exempted from customs duty and import duty; and
6) Generation based incentives in line with solar/wind energy programmes may be considered.

Sale of power: Transmission of the generated electricity to the nearest grid is the responsibility of the producer. Assured PPA for 25% of the electricity has been provisioned in the draft policy.

Direct uses of geothermal energy: Direct uses can be an option at sites where transportation and transmission of electricity or water may be difficult due to the remoteness of the area. Cascade use of geothermal water from power generating plants has also been proposed. Use of geothermal heat pumps or ground source heat pumps should be given priority in the draft policy. Various direct uses have been mentioned in the policy and it has been proposed to execute these applications for local use. It has been proposed that a license for direct heat use, where a proposal for electricity generation has not been submitted, is granted separately from the prospecting and exploration licenses for electrical projects. The draft policy proposes that state governments should provide necessary infrastructure facilities for direct use applications. Furthermore, that the direct heat use schemes are treated as vehicles for infrastructure development and the Central Government may contribute 30% of the project cost in form of incentives and funding up to Rs 50,000/TR. The state government may also contribute in form of land and licenses. The entrepreneur is expected to contribute the remaining amount of the project cost including the funding generated from commercial institutions at his own risk. As heat pumps already qualify for 80% accelerated depreciation during the first year of installation, the Ministry will ensure import duty exemptions during the first 3 years of the project while Indian industries cannot yet produce the required technology.

Public-private partnership: Since geothermal development is capital-intensive, policy proposes partnerships between the private, public and government sectors, suggesting that technology flow and assessment of resources may be supervised by the public and government sectors, while the field operations and logistics may be managed by the private sector. The involvement of foreign entities may be encouraged for exploration and development of geothermal resources, provided the "foreign collaboration" is tied up with technology transfer as 100% FDI is allowed in the renewable energy sector. Incentives need to be provided to private players considering the fact that geothermal power projects are capital-intensive and risk-prone and therefore require major investor support and private participation for early and steady development of geothermal resources. The following measures have been proposed in the policy document:

a. Awarding of a suitable area of land for developing the project and maintenance of production wells, thereby securing the commercial viability of the project. The State Governments should make land acquisition for development of geothermal energy projects a priority.
b. The Government should provide land on lease at price levels charged to government departments.
c. Incentives similar to other renewable energy programs in India, namely solar and biomass, may be granted. The Return on Equity (ROE) for geothermal projects could also be made comparable to other power projects in India, thereby ensuring reasonable earnings. The ROE for these projects could be higher than for other projects due to the additional risk associated with geothermal exploration.
d. Import subsidies may be granted to minimize the cost for the project, as most of the equipment for the project will be imported.
e. The foreign investors may be provided with investor friendly schemes for repatriation of profits.
f. Direct and indirect tax benefits may be granted at par with solar or biomass energy projects to support the high cost of exploration and power generation and to encourage private participation in the geothermal industry.
g. Direct heat utilization methods which replace fossil-fuel based electric power may be granted similar incentives.

APPENDIX II: Major policies in the renewable energy sector in India

No.	IEA/ IREA code	Name of policy	Type of policy	Target sector	Major benefits
1	53	*The Electricity Act 2003.* **Source:** Central Electr. Regulatory Commission, GoI. (in force)	Regulatory mechanism	Hydro power	Policy addresses issues related to rural electrification, generation - delicensing, transmission - open access, and setting up of regulatory commissions at central and state level (except J&K). Tariff policy.
2	52	*Government assistance for renewable energy projects (wind, solar, biofuel, hydro).* **Source**: Ministry of New and Renewable Energy (in force)	Economic instruments, fiscal/financial incentives, tax relief, loans	Hydro power and other renewable energy sources	The impact of fiscal and financial incentives, i.e., tax benefits, capital subsidy, depreciation of benefits not substantial to mechanism improvement. Financial viability is highly sensitive to preferential tariff and success/failure of the project is highly dependent on it. Benefits under SDF schemes have reduced project costs by 10%, through an attractive tariff.
3	49	*National Electricity Policy, 2005* **Source:** Government of India: Ministry of Power. (ended, 2012)	Policy reinforce Strategic planning, Regulatory mechanism, codes and standards, Auditing regulatory, Monitoring regulatory and other mandatory requirements	Multiple renewable energy sources	Access to electricity - available for all households in next five years. Availability of power - demand met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve available. Supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates. Per capita availability of electricity increased to over 1000 units by 2012. Minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012. Financial turnaround and commercial viability of electricity. Protection of consumers' interests.
3	48	*Tariff Policy 2006* **Source:** Ministry of Power, Government of India (in force). Protection of consumers' interests.	Regulatory instruments obligation schemes, economic instruments, fiscal/financial incentives, feed-in tariff premiums, policy support	Multiple common RE sources for large and small size	Reasonable cost of electricity for end users. Attractive investment plans for financial viability. Promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks. Promote competition efficiency. Initiatives in improving quality of supply.
4	44	*Solar and wind power generation-based incentives.* **Source**: Ministry of New and Renewable Energy, GoI (in force)	Economic instruments, fiscal/financial incentives taxes, and feed-in tariffs/premium, policy support, strategic planning, regulatory framework	Multiple renewable energy sources, solar, wind, solar photovoltaic	Through this policy, MNRE (2008) attracted developers by offering incentives for investments in development of wind and solar power plants in order to chase a target of 10,500 MW from new wind power plants. Developers were offered INR 0.5/kWh for ten years much higher than tariff determined for wind power by relevant regulatory authorities. The tariff does not apply to investors setting up capacities for captive consumption, third party sale, merchant plants, and to those benefiting from depreciation under the Income Tax Act. The

No.	IEA/ IREA code	Name of policy	Type of policy	Target sector	Major benefits
					payment will be funded by the MNRE, disbursed through the Renewable Energy Development Agency (IREDA) on a half-yearly basis.
5	38	*Jawaharlal Nehru National Solar Mission (phase wise). Last revised in 2017.* **Source**: MNRE, GoI (in force)	Reg. framework economic benefits, tax relief financial incentives, assured PPAs subsidies for R&D projects regulatory	Solar thermal, solar, solar photovoltaic	The Jawaharlal Nehru National Solar Mission (JNNSM) is an initiative of GoI and state governments to promote solar power in India. The scheme was launched with the aim to harness 100 GW by 2022. It was launched in 2010 in a phase wise manner with varying factors based on the local requirements.
	36	*Renewable Energy Certificate System, 2011.* **Source**: National Load Dispatch Centre (NLDC) Ministry of Power, GoI (in force)	Green certificates, regulatory. assured PPA through regulatory compliance	Multiple renewable energy sources mainly, generation of power	GoI through NLDC launched a Renewable Energy Certificates (RECs) system in 2011, which made it mandatory to all the states to contribute through renewable energy sources in total energy mix. RECs through Renewable Portfolio Obligation targets became mandatory for all states. In 2010, 5% of the total energy was generated from renewable sources, 6% in 2011, 7% in 2012, 8% in 2013, 9% in 2014 and 10% in 2015, and almost 22% in 2019. The mechanism is based on the RECs regulations notified by the Central Electricity Regulatory Commission (CERC) on January 14, 2010. Through the RECs mechanism, a pan-Indian market was created for trading of RECs through power exchanges. Sale of green energy to the obligated entities (Captive Power Plants/Open Access Consumers, DISCOMs) wherein a buyer uses the purchased energy for compliance of RPO. In such cases, renewable energy generator(s) are not eligible for registration and issuance of RECs.
6	21	*Accelerated depreciation tax benefit, 2014 (last amended 2017)* **Source**: MNRE, GoI (in force)	Tax benefits commercial and industrial users	Solar power/ energy	This policy was floated to promote the use of solar power by commercial and industrial users by making it possible for its users to depreciate investment in a solar power plant. The accelerated depreciation benefits the commercial and industrial users much faster than general fixed assets. This in return allows the user to claim tax benefits on the value depreciated in a given year.
8	18	*India 175 GW renewable energy target for 2022.* **Source**: MNRE, GoI (in force)	Policy support for strategic development through benefits and incentives along with exemptions	Multiple renewable energy Sources	In order to reach the 175 GW target from renewable energy resources by 2022, 100 GW needs to come from solar, 60 GW from wind, 10 GW from biomass and 5 GW from small hydropower stations. Various incentives were being offered through this policy/ scheme: – Zero import duty on capital equipment and raw materials; – Low interest rates and priority sector lending;

No.	IEA/ IREA code	Name of policy	Type of policy	Target sector	Major benefits
					– Single window mechanism for all related permissions. The scheme also provides 25 years of PPA. Approx. 1,739 MW of wind power capacity was added in 2017-18.
10	3	*National wind-solar hybrid policy, 2018* **Source**: MNRE, GoI (in force)	Policy support for strategic planning	Solar and wind	Objective is to provide a framework for promotion of large grid connected wind-solar PV hybrid systems for efficient utilization of transmission infrastructure and land. The policy provides procurement of power from a hybrid project. The tariff is based on a transparent bidding process for which government entities may invite bids. Policy also permits use of battery storage in the hybrid projects to optimize the output and further reduce variability. It mandates the regulatory authorities to formulate necessary standards and regulations for wind-solar hybrid systems.
11	1	*Capital grants for off-grid and decentralized concentr. solar thermal techno-logies for com-munity cooking, process heat and space heating & cooling applicat.* **Source**: MNRE, GoI (in force)	Economic instruments, fiscal/financial incentives, grants and subsidies	Solar and solar heat	In 2018, MNRE issued capital grants support for Concentrated Solar Thermal (CST) until 2020. Financial incentives up to 30% of actual investment cost were infused in the projects during the different project phases. In the special category, project developers will receive between 40% and 60% of the capital costs.

APPENDIX III: Tariff models for geothermal power plants in Puga

TABLE 1: Tarif model for scenario S-I

Assumptions		**Installed capacity (MW)**	15	**Plant load factor**	75.0%	**Cost per MW (in Crores) INR**	16														
Design energy	98.55	MUs																			
Total project cost	168	Crores(INR)		**Tax**	**29.120%**	CERC															
Debt	117.6	Crores(INR)		**MAT**	**20.260%**	CERC															
Equity	50.4	Crores(INR)																			
Cost of land	0																				
Rate of interest		11.50%																			
Discounting factor		10.62%																			
Rate of return on equity		14%																			
O & M expenses		1.50%	**Spares escalation**																		
Annual increase in O & M expenses		4%	6%																		
Interest on working capital		9.97%																			
Annual enegy generation Mus		98.55																			
Net saleable energy Mus		97.5645																			
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
O&M cost	2.52	2.62	2.73	2.83	2.95	3.07	3.19	3.32	3.45	3.59	3.73	3.88	4.03	4.20	4.36	4.54	4.72	4.91	5.11	5.31	
Interest on loan	12.85	11.50	10.14	8.79	7.44	6.09	4.73	3.38	2.03	0.68											
Depreciation	7.98	7.36	6.74	6.12	5.50	4.88	4.26	3.64	3.02	2.40	1.77	1.68	1.59	0.28	0.27	0.27	0.27	0.27	0.26	0.26	
Advance against depreciation	3.78	4.40	5.02	5.64	6.26	6.88	7.50	8.12	8.74	9.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Interest on working capital	0.79	0.78	0.77	0.76	0.76	0.75	0.74	0.73	0.73	0.73	0.58	0.59	0.62	0.62	0.64	0.67	0.69	0.72	0.75	0.78	
Return on equity	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	
Income tax	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	
Total annual fixed cost	36.41	35.14	33.89	32.63	31.39	30.14	28.91	27.68	26.45	25.23	15.19	15.27	15.35	14.20	14.39	14.59	14.79	15.01	15.23	15.46	
Indicative tariff (Rs.per kWh)	3.73	3.60	3.47	3.34	3.22	3.09	2.96	2.84	2.71	2.59	1.56	1.56	1.57	1.46	1.47	1.50	1.52	1.54	1.56	1.59	
PV factor	1.00	0.90	0.82	0.74	0.67	0.60	0.55	0.49	0.45	0.40	0.36	0.33	0.30	0.27	0.24	0.22	0.20	0.18	0.16	0.15	9.03
Discounted tariff	3.73	3.26	2.84	2.47	2.15	1.87	1.62	1.40	1.21	1.04	0.57	0.52	0.47	0.39	0.36	0.33	0.30	0.28	0.25	0.23	25.28
Levelised tariff for 35 years	**2.80**																				
Levelised tariff for 12 years	**3.59**																				
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Particulars																					
Loan repayment schedule																					
Opening balance of loan	117.60	105.84	94.08	82.32	70.56	58.80	47.04	35.28	23.52	11.76											
Annual repayment of loan	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76											
Outstanding loan at year end	105.84	94.08	82.32	70.56	58.80	47.04	35.28	23.52	11.76	0.00											
Average loan during the year	111.72	99.96	88.20	76.44	64.68	52.92	41.16	29.40	17.64	5.88											
Annual interest payable	12.85	11.50	10.14	8.79	7.44	6.09	4.73	3.38	2.03	0.68											
DEPRECIATION																					
Opening block	151.20	139.44	127.68	115.92	104.16	92.40	80.64	68.88	57.12	45.36	33.60	31.83	30.15	28.55	28.28	28.00	27.73	27.46	27.20	26.93	
Depreciation	7.98	7.36	6.74	6.12	5.50	4.88	4.26	3.64	3.02	2.40	1.77	1.68	1.59	0.28	0.27	0.27	0.27	0.27	0.26	0.26	124.53
Advance against depreciation	3.78	4.40	5.02	5.64	6.26	6.88	7.50	8.12	8.74	9.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total depreciation	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76	1.77	1.68	1.59	0.28	0.27	0.27	0.27	0.27	0.26	0.26	
Closing block	139.44	127.68	115.92	104.16	92.40	80.64	68.88	57.12	45.36	33.60	31.83	30.15	28.55	28.28	28.00	27.73	27.46	27.20	26.93	26.67	
Residual value																					
WORKING CAPITAL																					
Receivable	6.07	5.86	5.65	5.44	5.23	5.02	4.82	4.61	4.41	4.21	2.53	2.54	2.56	2.37	2.40	2.43	2.47	2.50	2.54	2.58	
O & M expenses	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.34	0.35	0.36	0.38	0.39	0.41	0.43	0.44	
Spares for maintenance with escalation (%)	1.68	1.78	1.88	1.99	2.10	2.22	2.35	2.48	2.62	2.77	2.93	3.10	3.27	3.46	3.66	3.87	4.09	4.32	4.57	4.83	
Total working capital	7.96	7.85	7.75	7.66	7.58	7.50	7.43	7.37	7.32	7.28	5.77	5.97	6.17	6.18	6.42	6.68	6.95	7.24	7.54	7.85	
Interest on working capital	0.79	0.78	0.77	0.76	0.76	0.75	0.74	0.73	0.73	0.73	0.58	0.59	0.62	0.62	0.64	0.67	0.69	0.72	0.75	0.78	

TABLE 2: Tariff model for scenario S-II

Assumptions		Installed capacity (MW)	15	Plant load factor	75.0%	Cost per MW (in Crores) INR	16														
Design energy	98.55	MUs																			
Total project cost	240	Crores(INR)		**Tax**	**29.120%**	CERC															
Debt	168	Crores(INR)		**MAT**	**20.260%**	CERC															
Equity	72	Crores(INR)																			
Cost of land	0																				
Rate of interest		11.50%																			
Discounting factor		10.62%																			
Rate of return on equity		14%																			
O & M expenses		1.50%	**Spares escalation**																		
Annual increase in O & M expenses		4%	6%																		
Interest on working capital		9.97%																			
Annual enegy generation Mus		98.55																			
Net saleable energy Mus		97.5645																			
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
O&M cost	3.60	3.74	3.89	4.05	4.21	4.38	4.56	4.74	4.93	5.12	5.33	5.54	5.76	5.99	6.23	6.48	6.74	7.01	7.29	7.58	
Interest on loan	18.35	16.42	14.49	12.56	10.63	8.69	6.76	4.83	2.90	0.97											
Depreciation	11.40	10.52	9.63	8.74	7.86	6.97	6.08	5.20	4.31	3.42	2.53	2.40	2.27	0.40	0.39	0.39	0.38	0.38	0.38	0.37	
Advance against depreciation	5.40	6.28	7.17	8.06	8.94	9.83	10.72	11.60	12.49	13.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Interest on working capital	1.13	1.12	1.10	1.09	1.08	1.07	1.06	1.05	1.04	1.04	0.82	0.85	0.88	0.88	0.91	0.95	0.99	1.03	1.07	1.12	
Return on equity	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08	
Income tax	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	
Total annual fixed cost	52.01	50.21	48.41	46.62	44.84	43.06	41.30	39.54	37.79	36.05	21.70	21.81	21.93	20.29	20.56	20.84	21.13	21.44	21.76	22.09	
Indicative tariff (Rs.per kWh)	5.33	5.15	4.96	4.78	4.60	4.41	4.23	4.05	3.87	3.69	2.22	2.24	2.25	2.08	2.11	2.14	2.17	2.20	2.23	2.26	
PV factor	1.00	0.90	0.82	0.74	0.67	0.60	0.55	0.49	0.45	0.40	0.36	0.33	0.30	0.27	0.24	0.22	0.20	0.18	0.16	0.15	9.03
Discounted tariff	5.33	4.65	4.05	3.53	3.07	2.66	2.31	2.00	1.73	1.49	0.81	0.74	0.67	0.56	0.51	0.47	0.43	0.40	0.36	0.33	36.11
Levelised tariff for 35 years	**4.00**																				
Levelised tariff for 12 years	**5.13**																				
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Particulars																					
Loan repayment schedule																					
Opening balance of loan	168.00	151.20	134.40	117.60	100.80	84.00	67.20	50.40	33.60	16.80											
Annual repayment of loan	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80											
Outstanding loan at year end	151.20	134.40	117.60	100.80	84.00	67.20	50.40	33.60	16.80	0.00											
Average loan during the year	159.60	142.80	126.00	109.20	92.40	75.60	58.80	42.00	25.20	8.40											
Annual interest payable	18.35	16.42	14.49	12.56	10.63	8.69	6.76	4.83	2.90	0.97											
DEPRECIATION																					
Opening block	216.00	199.20	182.40	165.60	148.80	132.00	115.20	98.40	81.60	64.80	48.00	45.47	43.07	40.79	40.40	40.00	39.62	39.23	38.85	38.47	
Depreciation	11.40	10.52	9.63	8.74	7.86	6.97	6.08	5.20	4.31	3.42	2.53	2.40	2.27	0.40	0.39	0.39	0.38	0.38	0.38	0.37	177.90
Advance against depreciation	5.40	6.28	7.17	8.06	8.94	9.83	10.72	11.60	12.49	13.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total depreciation	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	2.53	2.40	2.27	0.40	0.39	0.39	0.38	0.38	0.38	0.37	
Closing block	199.20	182.40	165.60	148.80	132.00	115.20	98.40	81.60	64.80	48.00	45.47	43.07	40.79	40.40	40.00	39.62	39.23	38.85	38.47	38.10	
Residual value																					
WORKING CAPITAL																					
Receivable	8.67	8.37	8.07	7.77	7.47	7.18	6.88	6.59	6.30	6.01	3.62	3.63	3.66	3.38	3.43	3.47	3.52	3.57	3.63	3.68	
O & M expenses	0.30	0.31	0.32	0.34	0.35	0.36	0.38	0.39	0.41	0.43	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.61	0.63	
Spares for maintenance with escalation (%)	2.40	2.54	2.68	2.84	3.00	3.17	3.35	3.54	3.75	3.96	4.19	4.43	4.68	4.95	5.23	5.53	5.84	6.18	6.53	6.91	
Total working capital	11.37	11.22	11.08	10.94	10.82	10.71	10.61	10.53	10.45	10.39	8.25	8.52	8.81	8.83	9.17	9.54	9.93	10.34	10.77	11.22	
Interest on working capital	1.13	1.12	1.10	1.09	1.08	1.07	1.06	1.05	1.04	1.04	0.82	0.85	0.88	0.88	0.91	0.95	0.99	1.03	1.07	1.12	

TABLE 3: Tariff model for scenario S-III

Assumptions		Installed capacity (MW)	15	Plant load factor	75.0%	Cost per MW (in Crores) INR	16														
Design energy	98.55	MUs																			
Total project cost	194.6	Crores(INR)		**Tax**	**29.120%**	CERC															
Debt	136.22	Crores(INR)		**MAT**	**20.260%**	CERC															
Equity	58.38	Crores(INR)																			
Cost of land	0																				
Rate of interest		11.50%																			
Discounting factor		10.62%																			
Rate of return on equity		14%																			
O & M expenses		1.50%	**Spares escalation**																		
Annual increase in O & M expenses		4%	6%																		
Interest on working capital		9.97%																			
Annual enegy generation Mus		98.55																			
Net saleable energy Mus		97.5645																			
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
O&M cost	2.92	3.04	3.16	3.28	3.41	3.55	3.69	3.84	3.99	4.15	4.32	4.49	4.67	4.86	5.05	5.26	5.47	5.69	5.91	6.15	
Interest on loan	14.88	13.32	11.75	10.18	8.62	7.05	5.48	3.92	2.35	0.78											
Depreciation	9.25	8.53	7.81	7.09	6.37	5.65	4.93	4.21	3.49	2.77	2.05	1.95	1.84	0.32	0.32	0.31	0.31	0.31	0.31	0.30	
Advance against depreciation	4.37	5.09	5.81	6.53	7.25	7.97	8.69	9.41	10.13	10.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Interest on working capital	0.92	0.91	0.90	0.88	0.87	0.87	0.86	0.85	0.85	0.84	0.67	0.69	0.71	0.71	0.74	0.77	0.80	0.84	0.87	0.91	
Return on equity	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	
Income tax	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	
Total annual fixed cost	42.17	40.71	39.25	37.80	36.36	34.92	33.49	32.06	30.64	29.23	17.60	17.68	17.78	16.45	16.67	16.90	17.13	17.38	17.64	17.91	
Indicative tariff (Rs.per kWh)	4.32	4.17	4.02	3.87	3.73	3.58	3.43	3.29	3.14	3.00	1.80	1.81	1.82	1.69	1.71	1.73	1.76	1.78	1.81	1.84	
PV factor	1.00	0.90	0.82	0.74	0.67	0.60	0.55	0.49	0.45	0.40	0.36	0.33	0.30	0.27	0.24	0.22	0.20	0.18	0.16	0.15	9.03
Discounted tariff	4.32	3.77	3.29	2.86	2.49	2.16	1.87	1.62	1.40	1.21	0.66	0.60	0.54	0.45	0.42	0.38	0.35	0.32	0.29	0.27	29.28
Levelised tariff for 35 years	**3.24**																				
Levelised tariff for 12 years	**4.16**																				
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Particulars																					
Loan repayment schedule																					
Opening balance of loan	136.22	122.60	108.98	95.35	81.73	68.11	54.49	40.87	27.24	13.62											
Annual repayment of loan	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62											
Outstanding loan at year end	122.60	108.98	95.35	81.73	68.11	54.49	40.87	27.24	13.62	0.00											
Average loan during the year	129.41	115.79	102.17	88.54	74.92	61.30	47.68	34.06	20.43	6.81											
Annual interest payable	14.88	13.32	11.75	10.18	8.62	7.05	5.48	3.92	2.35	0.78											
DEPRECIATION																					
Opening block	175.14	161.52	147.90	134.27	120.65	107.03	93.41	79.79	66.16	52.54	38.92	36.87	34.92	33.07	32.75	32.44	32.12	31.81	31.50	31.20	
Depreciation	9.25	8.53	7.81	7.09	6.37	5.65	4.93	4.21	3.49	2.77	2.05	1.95	1.84	0.32	0.32	0.31	0.31	0.31	0.31	0.30	144.25
Advance against depreciation	4.37	5.09	5.81	6.53	7.25	7.97	8.69	9.41	10.13	10.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total depreciation	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	2.05	1.95	1.84	0.32	0.32	0.31	0.31	0.31	0.31	0.30	
Closing block	161.52	147.90	134.27	120.65	107.03	93.41	79.79	66.16	52.54	38.92	36.87	34.92	33.07	32.75	32.44	32.12	31.81	31.50	31.20	30.89	
Residual value																					
WORKING CAPITAL																					
Receivable	7.03	6.78	6.54	6.30	6.06	5.82	5.58	5.34	5.11	4.87	2.93	2.95	2.96	2.74	2.78	2.82	2.86	2.90	2.94	2.99	
O & M expenses	0.24	0.25	0.26	0.27	0.28	0.30	0.31	0.32	0.33	0.35	0.36	0.37	0.39	0.41	0.42	0.44	0.46	0.47	0.49	0.51	
Spares for maintenance with escalation (%)	1.95	2.06	2.17	2.30	2.43	2.57	2.72	2.87	3.04	3.21	3.39	3.59	3.79	4.01	4.24	4.48	4.74	5.01	5.30	5.60	
Total working capital	9.22	9.10	8.98	8.87	8.77	8.69	8.61	8.54	8.48	8.43	6.69	6.91	7.15	7.16	7.44	7.74	8.05	8.38	8.73	9.10	
Interest on working capital	0.92	0.91	0.90	0.88	0.87	0.87	0.86	0.85	0.85	0.84	0.67	0.69	0.71	0.71	0.74	0.77	0.80	0.84	0.87	0.91	