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UNFC Classification of Himalayan Geothermal System in India

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ABSTRACT

The Himalayan geothermal systems in India encompasses the Puga & Chumatang provinces of Laddakh region which has a conservative estimate of generating in excess of 500 MWe. Albeit such a strong potential energy production efforts have been unable to take off in spite of numerous attempts by various stakeholders as it has hit road blocks from time to time.

The Energy Sector Management Assistance Program of the World Bank Group (ESMAP) - International Geothermal Association (IGA), and International Renewable Energy Agency (IRENA), have made a joint effort to adopt United Nations Framework Classification (UNFC) to geothermal energy resources. Popularly known as UNFC-2009 is gaining popularity with stakeholders worldwide. An attempt is now being made to apply the guidelines to both the real-world geothermal projects on an “as in where in” condition basis to help stakeholders understand the underlying problems. It’s imperative to identify the bottlenecks and further make collective and sustain efforts to harness the abundant geothermal potential of the region. Geothermal energy development in the state have the ability to be a direct catalyst in the social-economic development of the region.

Moving further, there will be an overview understanding of UNFC framework which has been supported by United Nations Economic Commission for Europe (UNECE) , a view of the Puga Geothermal field , and there on attempt to apply the UNFC guidelines to these real-world geothermal projects , and understand its complexity.

1. INTRODUCTION

1.1 A brief overview of UNFC- 2009 application to Geothermal Energy Resource

UNFC-2009 applies to fossil fuel and mineral reserves and resources located on or below the Earth’s surface. It has been designed to meet, to the extent possible, the needs of applications pertaining to energy and mineral studies, resources management functions, corporate business processes and financial reporting standards. (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application ece energy series no. 42)

As per UNFC – 2009, geothermal energy resource is the gross quantity of heat or electrical energy estimated to be produced by the geothermal resource during its lifetime

UNFC-2009 was designed to be a generic principle-based system, which has been applied to geothermal energy resource in which quantities are classified on the basis of the three fundamental criteria of economic and social viability (E), field project status and feasibility (F), and geological knowledge (G), using a numerical coding system (Figure 1). Combinations of these criteria create a three-dimensional system. Categories (e.g. E1, E2, E3) and, in some cases, sub-categories (e.g. E1.1). The first set of categories (the E axis) designates the degree of favorability of social and economic conditions in establishing the commercial viability of the project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development projects (Figure 1). These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist through to a project that is extracting and selling a commodity, and reflect standard value chain management principles. The third set of categories (the G axis) designates the level of confidence in the geological knowledge and potential recoverability of the quantities. The categories and sub-categories are the building blocks of the system, and are combined in the form of “classes”. UNFC-2009 can be visualized in three dimensions, as shown in Figure 1 (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application ece energy series no. 42 page no 2).

The proper application of UNFC-2009 to a green field geothermal resources project has the potential to gauge and predict the practicality of the socio-economic and non – technical feasibility criteria’s of the project development and sustainability life cycle. More often than not one does come across scenarios when a geothermal project is technically and financial viable but would never see the light of the day due to its social, policy, and non-technical issues.

2. PUGA (HIMALAYAN) GEOTHERMAL SYSTEM

2.1 Introduction

The geothermal provinces in India are associated either with deep seated rift systems, like East Africa, or are associated with continental collision zones (Figure 1). The temperature of the thermal springs measured at the surface varies from 47 to 98 °C. One common feature of all these provinces, as reported earlier (Chandrasekhar and Chandrasekharam, 2007), is that they circulate within the continental crust and are hosted by high heat generating granites. Thus, it seems that the entire wet geothermal systems in India are driven by high heat generating granites. Geothermal power projects have been initiated in three such provinces of Godavari rift, Puga and Tattapani. The Godavari rift geothermal project has the Govt. clearance and at present negotiations are on to fix the power tariff by M/s GeoSyndicate Power Pvt. Ltd. The entire Himalayan Geothermal Belt (HGB) is associated with convergent continental plate boundaries that extend from Nangaparbat (NW) to Arunachal Pradesh (Figure 2.). The geothermal system is driven here by shallow emplaced granitic melts and also by the presence of high heat generating younger leuco granites located all along the entire HGB.

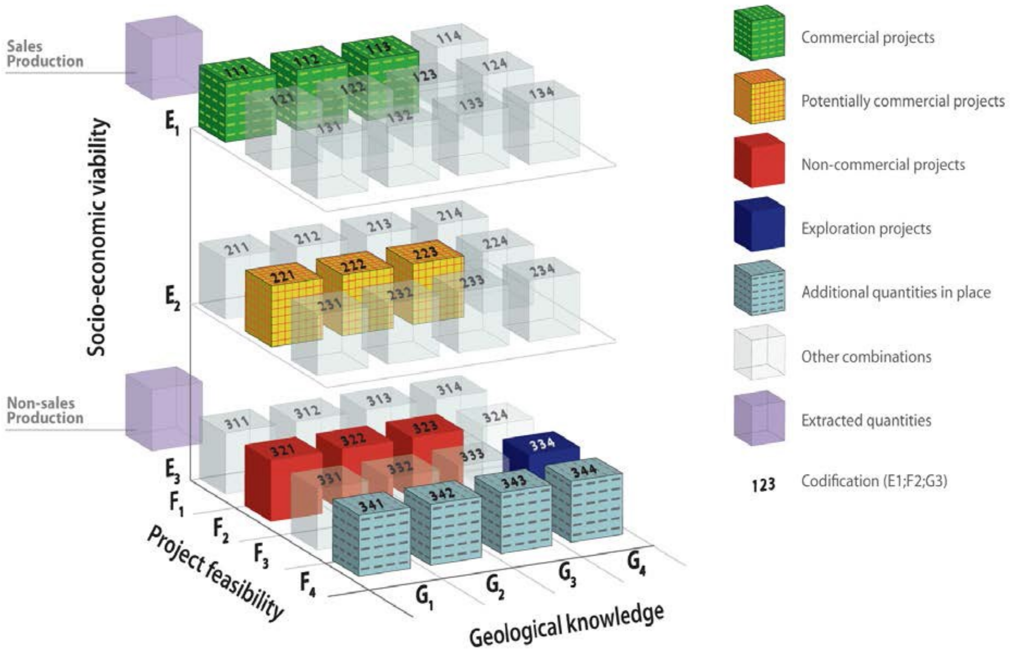

Figure 1. UNFC-2009 Categories and Examples of Classes (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application ece energy series no. 42, Page no 3)

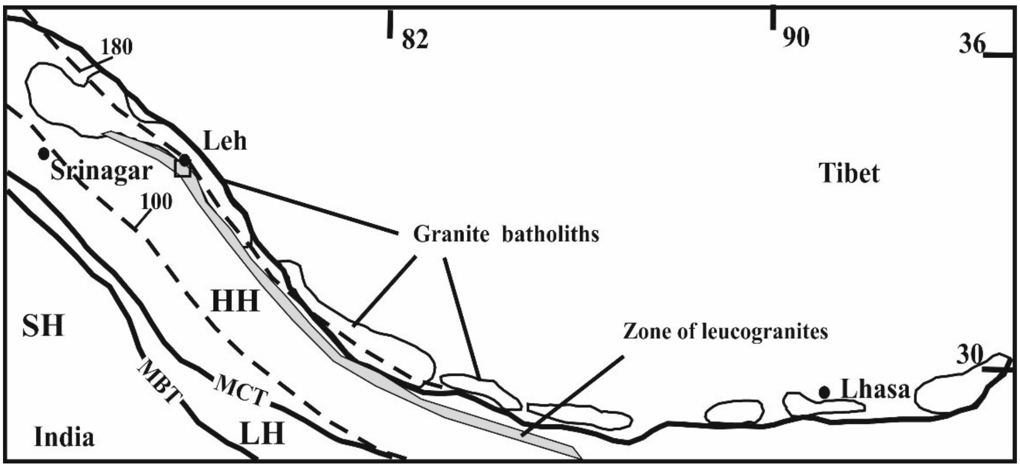

Figure 2. The Himalayan Geothermal Belt (HGB in Fig.1) showing granite intrusive, the Main Central Thrust (MCT), the Main Boundary Thrust (MBT) and the heat flow contours. SH: Siwalik Himalayas, LH: Lower Himalayas; HH: Higher Himalayas. Puga geothermal province is located 135 km south of Leh. South Tibetan Detachment System (STDS) lies SW of Lhasa (modified after Chandrasekhar and Chandrasekharam, 2007).

2.2 Himalayan Tectonics

The Himalayan Geothermal Belt (HGB) has evolved due to the collision of Indian and Eurasian plates that are converging at a rate of about 50 mm/y (Minster and Jordan, 1978*)*. The occurrence of high grade metamorphic rocks suggest vertical transport of lower crustal rocks while the younger post collision granites indicate continuous perturbations of the temperature structure of the entire HGB (Le Fort, 1981). Since the evolution of the geology and tectonics occurred parallel to the collision zone, a series of terrains parallel to the HGB evolved with well-defined thermal zones, with higher heat flow value contour running parallel to the collision zones along the upper Himalayas while the lower heat flow value contour lying parallel along the lower Himalayas (Fig.3.). These parallel terrains have similar lithological types. Due to such monotonous geological and tectonic features, cross sections at any part of this belt show similarity in lithology and tectonic framework. The most significant tectonic features of the HGB is the Main Central Thrust (MCT) (Figure 2) and the South Tibetan Detachment System (STDS) (Harrison et al., 1999). Major thrust and magmatic activity in the HGB occurs along the MCT and the igneous intrusions are represented by younger leucogranites (Fig. 2). The thrust along the MCT is the main source of heat (shear heating) that along with the high radioactive element concentration in the thrusted high grade metamorphic crystalline is responsible for the formation leucogranitic melts (Harris et al., 2000).

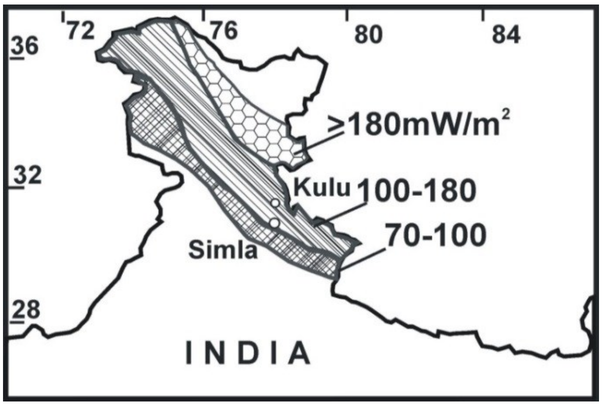

Figure 3. Heat flow values of NW Himalayas (modified after Chandrasekharam, 2001)

2.3 Heat source and geothermal systems along HGB

The location of thermal springs along the north-western part of HGB is shown in Figure 4. The surface temperature of thermal springs located south of MCT vary from 57 to 98 °C (Alam, 2002) while those located north of the MCT vary from 80 to 85 °C. The thermal springs located north of MCT are at an elevation of 5000 m and hence all the springs are in a state of boiling (Puga geothermal province, Leh). These thermal fluids are circulating within the granites that are generated, as described above, through anatectic melting of subducting pelitic sediments and the continental crust. The estimated reservoir temperatures are > 280 °C for Puga geothermal province (Chandrasekharam and Alam, 2004) while similar temperatures were reported from bore wells drilled (~ 1 km depth) at Yangbajing geothermal province of China (Kearey and HongBing, 1993, Dor Ji and Zhao Ping, 2000).

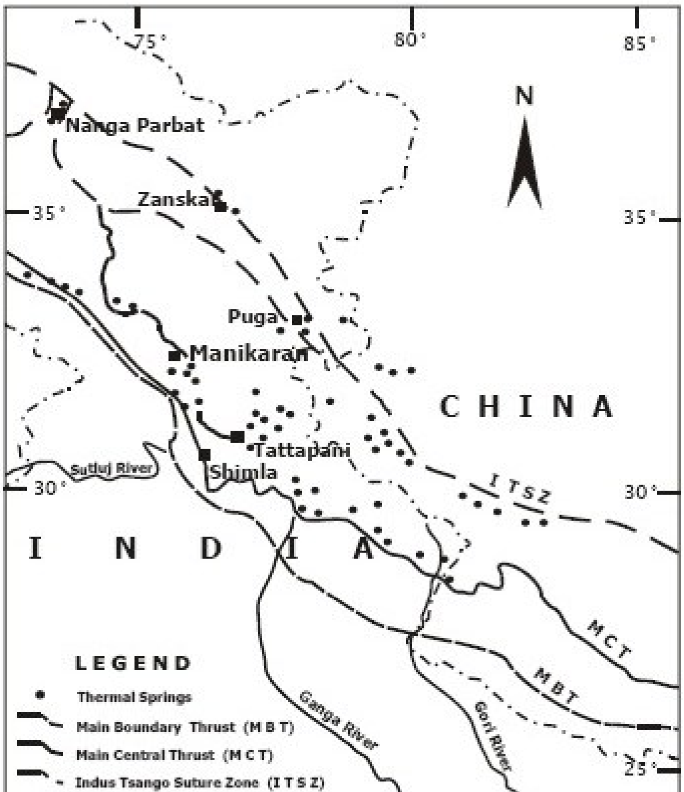

Figure 4. Location of thermal springs of NW Himalayas. ITSZ indicate Indo-Tibet Suture Zone (modified after Chandrasekharam et al., 2003)

The concentration of U, Th and K content in the leucogranites vary from 2 to 16 ppm, 3 to 36 ppm and 3 to 4 % respectively (Liu et al., 2006, Zeng et al., 2011, Tartese and Boulvais, 2010, Harrisson et al. 1999). The heat generated by these granites vary from 3.1 to 5 $\mu W/m^3$. This heat, together with shear heating of the subducting slab along the MCT and decompressional melting due to normal faulting along MCT, are the main sources generating melts of leucogranites that are channelized along the mineral grain boundaries to shallower levels. These melts are generated, as described above, at depths varying from 25 to 30 km and are emplaced at a shallower level (at depths of about 5 to 7 km) through feeder dykes (Harris et al., 2000) and or as sill complexes at shallower levels (Searle, 1999). Such shallow thermal anomalies are the main source generating geothermal fluids and reservoirs along the entire HGB. The composition of the geothermal fluids as reported earlier (Chandrasekharam and Alam, 2004) are saline with chloride content varying from 377 to 382 mg/L. High chloride levels at such elevation can only be explained by the mixing of magmatic fluids (as documented from fluid inclusion in quartz grains in the leucogranites) that are saline in composition (Sachan, 1996). The boron content in the thermal fluids is high varying from 130 to 300 mg/L (Chandrasekharam and Alam, 2004) indicating their circulation within the hot leucogranites that are enriched in B content (932 to 1070 mg/L, Visona and Lombrdo, 2002) compared to continental crust with B content of 9 to 10 mg/L, (Turekian and Wedephol 1961). Surface borax manifestation (white borax powder deposited over the surface) is common in all the geothermal sites of HGB (Puga in Ladakh district and Yangbajing in China and Tibet; Chandrasekharam and Alam, 2004, Kearey and HongBing, 1993, Grimaud et al., 1985). In fact, borax is being mined commercially from the Yangbajing geothermal province of China.

3. APPLYLING UNFC-2009 GUILELINES TO PUGA GEOTHERMAL PROJECT (PGP)

3.1 Overview of the classification nomenclature to be applied to PGP

The UNFC – 2009 nomenclature could be a little complex structure to begin with given the three dimensional axis of classification followed by three sub classes to each axis thus giving any particular greenfield project over a two dozen outcomes. Using the simplified (Figure 5) 2D view of the nomenclature we shall attempt to classify PGP along the three axis and sub classes.

	Extracted	Sales Production			
		Non-Sales Production[a]			
		Class	Categories		
			E	F	G[b]
Total Commodity Initially in Place	Future recovery by commercial development projects or mining operations	Commercial Projects[c]	1	1	1, 2, 3
	Potential future recovery by contingent development projects or mining operations	Potentially Commercial Projects[d]	2[e]	2	1, 2, 3
		Non-Commercial Projects[f]	3	2	1, 2, 3
	Additional quantities in place associated with known deposits[g]		3	4	1, 2, 3
	Potential future recovery by successful exploration activities	Exploration Projects	3	3	4
	Additional quantities in place associated with potential deposits[g]		3	4	4

Figure 5: UNFC-2009, showing Primary Classes in 2D representation

a). Future non-sales production is categorized as E3.1. Resources that will be extracted but not sold can exist for all classes of recoverable quantities. They are not shown in the figure; b). G categories may be used discretely, particularly when classifying solid minerals and quantities in place, or in cumulative form (e.g. G1+G2), as is commonly applied for recoverable fluids; c). Commercial Projects have been confirmed to be technically, economically and socially feasible. Recoverable quantities associated with Commercial Projects are defined in many classification systems as Reserves, but there are some material differences between the specific definitions that are applied within the extractive industries and hence the term is not used here; d). Potentially Commercial Projects are expected to be developed in the foreseeable future, in that the quantities are assessed to have reasonable prospects for eventual economic extraction, but technical and/or commercial feasibility has not yet been confirmed. Consequently, not all Potentially Commercial Projects may be developed, e). Potentially Commercial Projects may satisfy the requirements for E1; f). Non-Commercial Projects include those that are at an early stage of evaluation in addition to those that are considered unlikely to become commercially feasible developments within the foreseeable future; g). A portion of these quantities may become recoverable in the future as technological developments occur. Depending on the commodity type and recovery technology (if any) that has already been applied, some or all of these quantities may never be recovered due to physical and/or chemical constraints. (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application ece energy series no. 42, Page no 5).

3.2 PGP on G- Axis

G-axis representation helps in understanding the technical soundness of the geothermal resource. Hence all the technical parameters like geology, resource quantification & quality, permeability, porosity, temperature, depth come under the G-axis ambit. The number 1 to 4 denotes the level of confidence / soundness in the system.

The G - axis is further classified into four categories G1, G2, G3, and G4. Where-in G4 is specifically designated for understanding the probable potential of the given system which is still in very early stages of exploration that can become a resource .With confidence level rated from G 4.1 to G 4.3.

The G1-G3 sub categories come into play when the geothermal system potential is known and well demarcated. For Example G1 denotes the high confidence on the given geothermal energy resource hence enabling the professional to make a reliable estimation of the lifecycle of the given geothermal resource.

In case of PGP it may be noted from the earlier section the estimated reservoir temperature is in excess of 280 ^{o}C , with an estimated area of about 30 SqKM along with the Himalayan glaciers acting as nature recharge agents and subduction magmatic heat form as low as 3 KM (Chandrasekharam and Alam, 2004). Given these parameter it has been estimated that PGP like its sister field in Yangbajing (Kearey and HongBing, 1993, Grimaud et al., 1985). In Tibet, China can generate can generate over 350 MWe for a span of 100 years (Chandrasekharam and Chandrasekhar, 2010).

Given the quality of geothermal resource at PGP it can be classified as G1 under the UNFC-2009 Nomenclature.

Table 1: PGP along UNFC-2009 G Axis

	G Axis Analysis
Source Quantified	350MWe @ 30KM^2
Life of plant based on Source	Minimum 100 Years
Permeability	>65%
Depth	1800 Mts
Down hole temperature:	>280^{o}C
Recharge	Upper Shivaliks Glaciers
Heat Source	Shallow Subduction of Indian Plate below Asia plate
Hence Puga Geothermal Field can be Classified at G1	

3.3 PGP on E- Axis

E-axis representation helps in understanding the economic and social viability of the project. Hence parameters like FiT , Interest rates , RoI , Easy of acquiring land , resistance from local population , Regulatory support, Financial commitments etc comes under the E-axis ambit. The number 1 to 3 denotes the level of confidence / soundness in the system.

The E - axis is further classified into three categories E1, E2, E3 which come into play when the geothermal project has accounted for all the parameters into development plant with E1 denotes the higher confidence and probability that the project shall see the light of the day.

Laddakh once district of Jammu & Kashmir but now a Union Territory of India has a current need of 89 MWe with Leh, its capital city and hub for tourism, accounting for majority of the demand (LHDAC Report 2010). The estimated future demand including the need by military establishments is estimated to be 149 MWe by the year 2025 (LHDAC Report 2010). Currently the capital town of Leh is serviced by 7 diesel power plant and small hydro power plant, however the small hydro plant is non-operational during the winter months of October to March when the temperatures drops to - 20^{o}C. The diesel generator plant is not cost effective and at an altitude of 18000 ft above MSL the carbon emissions has the potential to create substantial respiratory health issues.

Given the situation, geothermal energy is a natural and reliable alternative which will support the economic and social development of the region, a thought process overwhelmingly supported by the local residents of the state. This makes power generation an attractive and safe investment option. PGP has received several investment and development proposals after careful techno-commercial diligence of the field.

This highlights and Critical Road Blocks of E – Axis criteria is highlighted in Table 2, which can be classified as E2.

Table 2: PGP along UNFC-2009 E Axis

Need/Demand For Electrification in the Area	89MWe / 140 Mwe on a 24x7 basis
FiT Contract	In-Process for over 7 years and Over due high risk on favourable FiT TOC acceptance
RoI as per Central Electric Regulatory Commission	16% (Inline with J&K State Spl Status PPA Policy)
Social Implication	Substantial Support received from Ladakh Counsil Over 5000 Direct and Indirect Job Creating 24x7 Clean base load Power Thought out Winter Eliminates black carbon health hazards Promotes Winter tourism
Capital Committed and Spent to complete exploration with Slim Well Drilling to Source	UNDP , GeoSyndicate Power Ltd , Panax Geothermal
In-Principle Capital commitment avalible subject to regulatory , FIT approval and NoC	GeoSyndicate Power Ltd , Panax Geothermal , Reykjavik Energy , Islandsbanki (through LNJ Bhilwara)
Hence Puga Geothermal Field can be Classified at E2	

3.4 PGP on F- Axis

F-axis representation helps in understanding the actual field project status and feasibility of the project. It is also is one of the most complex grading systems of economic and social viability of the project. For example, FiT contract is executed however its associated environmental No Objection Certificate or Date of commercial production is not written in stone, in such a scenario the project has the potential to be pushed into a downward spiral and delays become indefinite. In another example the faulty drill bit stuck up in a well for a prolonged time, prolonged delay in arrival of turbines, equipment has the potential to slip the project from F1 to F4.

Where in actual scenario a well-planned project though is natural course of from Exploration to Implementation to Operation and Management would go from F4 to F1. Any reverse movement demands the immediate attention of the stakeholders to take corrective action.

CONCLUSIONS

It’s now well observed that as per UNFC-2009 classification system PGP falls in the G1, E2.2, and F3 bracket. An area where in attracting investments would be a challenge. Under ideal conditions the desired classification bracket for PGP to run smoothly would be G1, E1, and F1.

In order to move to the higher classification bracket PGP shall need a decisive policy, regulatory and environmental support from the State Government which need to shake off its moment of Inertia and Policy Paralysis and give the much needed stimulus push.

It clear that having an excellent geothermal resource at the location which is technically and financial viable as a stand along greenfield project , for PGP to see the light of the day Laddakh the newly formed Union Territory of India a can now reconsider the project under the current political scenario to support it socio-economic development.

Table 3: PGP along UNFC-2009 F Axis

	PGP F Axis Analysis
Confirmed Off taker of Electricity	Leh ,City and Indian Armed Forces (Asset)
Confirmed Off taker for Heat (Asset)	Indian Armed Forces forward base (Asset)
Nearest Available 66 KV Dual Circuit Transmission Line in Leh City	180 KM away (Issue with a Solution in forgeable future)
Nearest Available 33 KV Single Circuit Transmission Line	66 KM away (Issue with a Solution in forgeable future)
Capital Commitment Received to complete exploration with Slim Well Drilling to Source	UNDP , GeoSyndicate Power Ltd , Panax Geothermal , SKM New Zealand
In-Principle Capital commitment subject to regulatory , FIT approval and NoC	GeoSyndicate Power Ltd , Panax Geothermal , Reykjavik Energy , Islandsbanki (through LNJ Bhilwara)
NoC from Laddakh Development Hill Council to commercial development in reserved tribal land	Supported by LDHAC Pending with Jammu & Kashmir Govt– 8 Years Reasons - Unknown
NoC on Environment – Government of India	Pending – 11 Years Resolution timeline: Unknown
Hence Puga Geothermal Field can be Classified at F3	

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