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Geothermal energy update of Nepal

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Nepal has witnessed steady progress in geothermal activities during the last three years. Dozens of new geothermal localities have been identified across the country with four manifestations with surface temperatures above 80 ºC including the largely ignored Kermi hot spring in Mugu district where the steaming water takes the form of a flowing river. A book on the hot springs in Nepal, the first of its kind, outlines the profile of a majority of hot springs and intends to motivate people from different sectors towards the need to promote the use of geothermal energy resources in Nepal. The country has also seen notable achievements in the development of infrastructure in many thermal locations mainly with the support of local communities and to some extent, the provincial governments. The significant sites are Darmija, Singa, and Paudwar (Myagdi district), Bulbul Taal (Surkhet district), Nundhaki (Sankhuwasabha district), and Chame (Manang district). A hydrotherapy center has been established in one of the country's leading hot springs at Singa.

The Water and Energy Commission of Nepal has sponsored a project to identify, charactirize hot spring in Nepal and develop a plan for geo-tourism in some potential spring sites.Besides, a few scientific studies and surveys have been conducted for the first time in Nepal. These include a survey involving patients in the Singa hot spring to examine the understanding, attitudes, beliefs, and perceptions of people taking on water.

An experiment was carried out on the stand-alone hybrid solar – geothermal Organic Ranking Cycle (ORC) technology for power generation at Bhurung hot spring with a surface temperature 69.7 °C. Likewise, another feasibility study was conducted at Paudwar hot spring with a surface temperature 66.2 °C and mass flow rate 6.48 kg/s for the same purpose using ORC technology. Both studies indicate that it is economically feasible to harness the hot spring water for power generation under different scenarios.

A study on design and analysis of geothermal cooling systems has been concluded in the Mahottari district in the Terai Region of Nepal. The designed geothermal cooling system was found to be much more efficient than a traditional air-cooled cooling system having a theoretical coefficient of performance (COP) of around 6.77 and an experimental coefficient of performance of around 4.63.

Enzymatic screening and molecular characterization of thermophilic bacterial strains isolated from a hot spring located at Bhurung, Myagdi district has confirmed that the isolated Bacillus sp. is a true thermophile and could be a source of various thermostable exoenzymes that can be exploited for pharmaceutical and industrials applications such as leather, food, and waste processing. All these activities indicate the growing interest to extend the use of hot spring waters beyond bathing and laundering.

1. INTRODUCTION

1.1 About Nepal

The country is officially known as the Federal Democratic Republic of Nepal, and it functions within the framework of a parliamentary republic with a multi-party system. Executive power is exercised by the Prime Minister and the cabinet, while legislative power is vested in the Parliament.

The population of Nepal according to Census Nepal 2021 is 29.19million.The male population constitutes 48.96% while the rest 51.04% is the females population, without consideration for people falling under LGBTQ. The population growth rate stands at 0.93%, the lowest in 80 years. The population density is 198 per km^2. After remaining as one of the 48 Least Developed Countries (LDCs) in the world for 50 years, Nepal passed to Developing Country status in November 2021 by meeting two of the three criteria set by the United Nations: gross national income per capita, human assets, and economic vulnerability.

1.2 Hot springs in Nepal

Manang, Mustang, Dolpa, Rasuwa, and Humla are the five districts of Nepal with a minimum population (in ascending order) that present hot springs. All these districts lie in the Northern part of Nepal, which lacks good road networks, and people migrate to the southern hilly or Terai plain to escape the cold temperature during winter. All the hot springs in these districts fall around the main central thrust. Five districts namely Kathmandu, Morang, Rupandehi, Jhapa, and Sunsari have the highest population (in descending order). However, none of these presents a single hot spring source.

The updated information shows that geothermal manifestations occur in at least 18 districts in Nepal (Fig. 2). Table 1 provides the locations of hot springs in each of these districts.

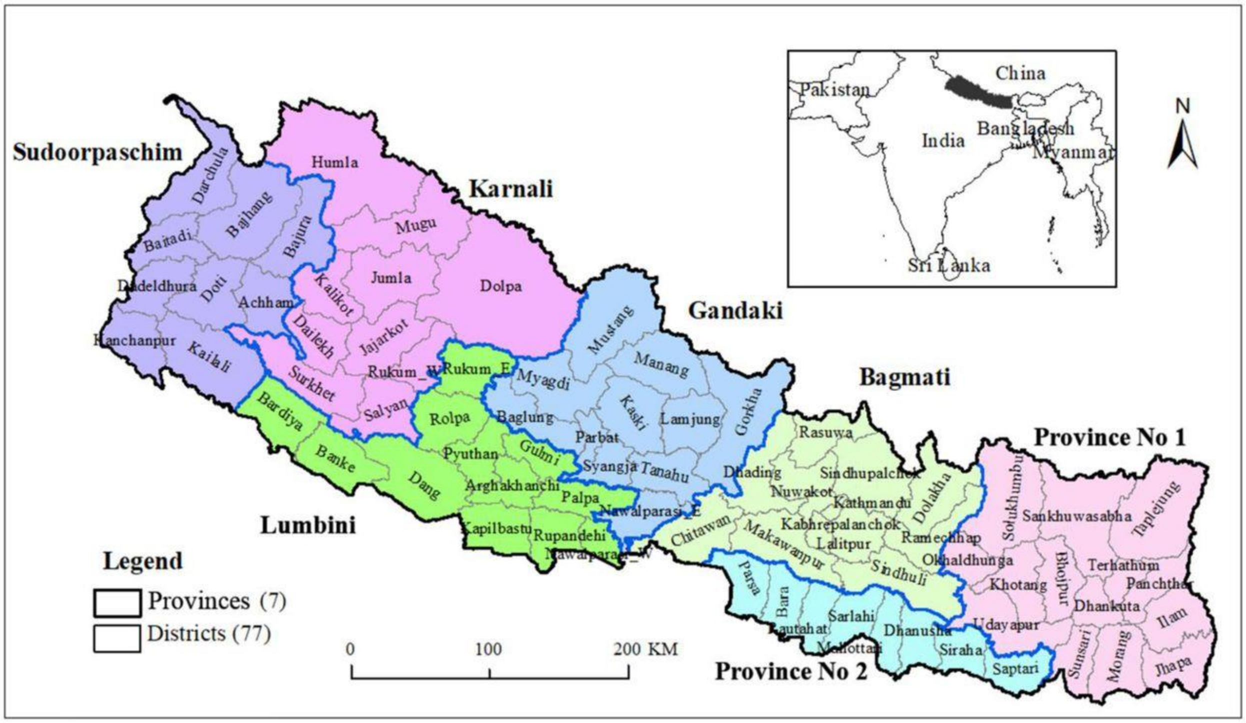

Figure 1: Map of Nepal in the world

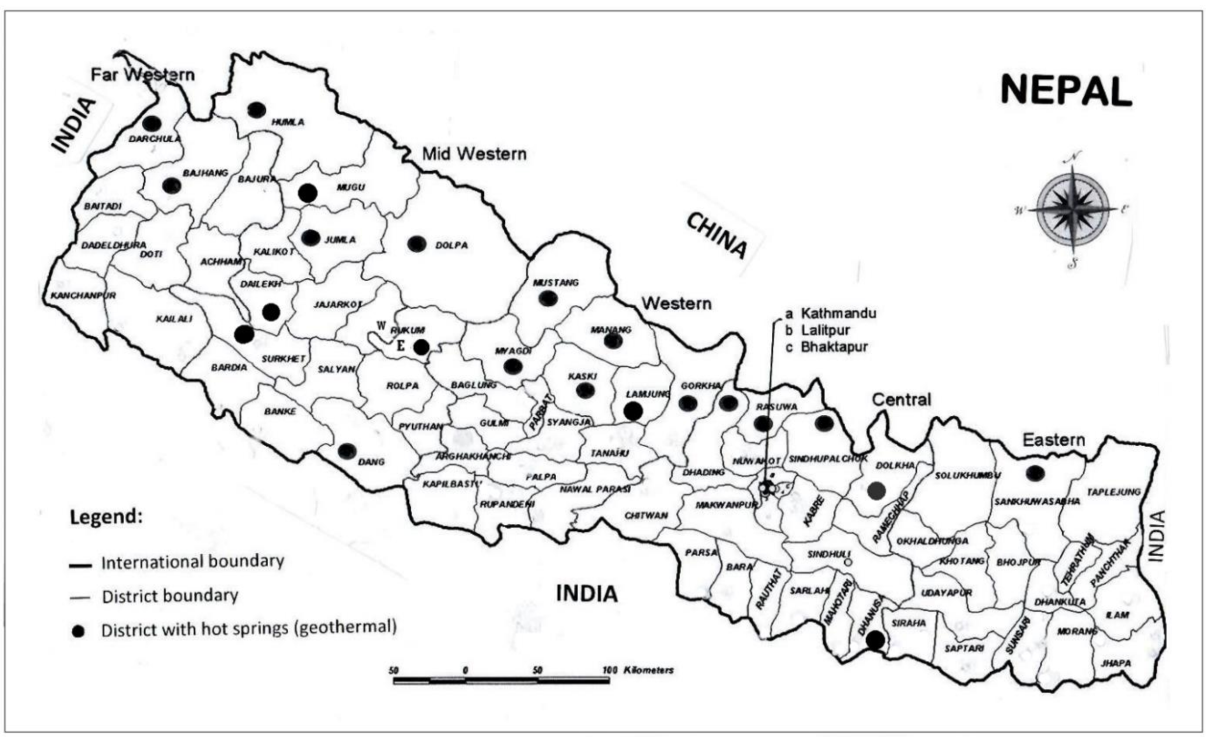

Figure 2: Districts showing hot springs in Nepal

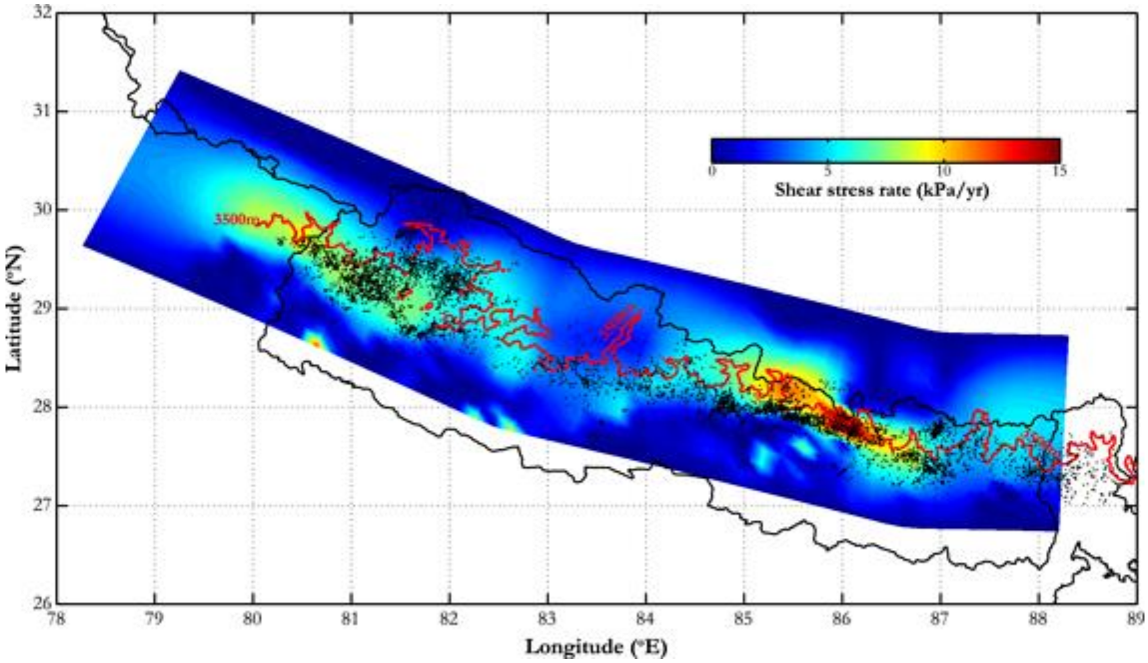

Figure 3 : Map view of the middle crustal microseismicity from 1996 to 2008 superposed to the map of the shear stress accumulation rate on the MHT, deduced from the coupling pattern.

The thick red line represents the 3500 m elevation contour line above which the seismicity seems to drop. Occurrence of hot springs in Nepal is in tune with the area around the red lines (main central thrust) in Nepal.

Table 1. Hot springs according to the geographical / administrative zone

FAR WESTERN NEPAL	
District	**Name of hot spring**
Darchula	Barapta, Dethala – Chameliya, Sina Tatopani, Tapoban-Sribagad
Bajhang	Chainpur, Jeoligadh, Tapoban-Bauligadh
MID-WESTERN NEPAL	
District	**Name of hot spring**
Jumla	Dhanchauri-Luma, Tilanadi
Humla	Chhurku, Aita (Takche), Takpachen, Kermi, Kharpu, Madapolan, Unapani, Sarlisalla
Mugu	Kachiyakot, Purumaru – Tatopani gufa, Ruwa – Bhusekuna, Soru – Jima Kulaha
Dolpa	Rupgadh, Shahatara
Dang	Rihar, Surai Khola
Surkhet	Bhulbhule Taal
East Rukum	Dimurgaira, Jarlung, Ranma, Maikot, Okhma. Dhaune, Pokhara, Jodu, Khara, Rala, Pelma and Birgum
WESTERN NEPAL	
Mustang	Charang, Chookumau, Dhi-Lomanthang, Jomsom, Muktinath
Manang	Chame, Dharapani, Makaibari
Myagdi	Bagara-Mudi, Bhurung, Dagnam, Darbang, Darmija, Folding Khola, Histan, Mayangdi, Paudwar (Lower Narchyang), Rato pani (Dhirchyang), Sekkar (Bega), Singa
Kaski	Chitepani – 1, Chitepani – 2, Chhomrong, Down Batase, Jamile, Jhinu, Kharpani - Sardi Khola, Machhapuchhre base camp, Mirsa - Seti Khola, Naya Gaun, Sadhu Khola, Seti Khola (north of Kharpani), Up Batase
Lamjung	Bahundanda -1, Bahundanda -2, Bhotewodar - Marshyangdi River, Jagat, Seti Khola
Gorkha	Arughat, Bhulbhulekhar, Khoplang, Machha Khola – Uhiya, Tatopani - Khorlabesi
CENTRAL NEPAL	
Rasuwa	Chilime, Chilime-Sanjen, Lende Khola – Bahundanda, Pargang, Syabrubesi, Timure – Sedang, Thuman
Dhading	Chalis(e), Linjo-Tipling, Jharlang

Sindhupalchowk	Kodari
Dolakha	Gonggar
EASTERN NEPAL	
Dhanusha	Janakpur
Sankhuwashabha	Bhotkhola, Hatiya, Nundhaki

Some other hot springs have been identified in East Rukum district (Pokhara, Jodu, Khara, Jharlung, Rala, Okhma, Pelma, Maikot and Birgum), Myagdi district (Bhale Basne Taal and Dhadkhark), Sindhupalchowk district (Sailung) and Dolpa district (Suligadh).

Notable information has been obtained about the hot springs in Humla and East Rukum districts.

2. STATUS OF HOT SPRINGS IN SOME DISTRICTS

2.1 Humla district

The update period has identified at least eight hot springs in Humla district. Four of these are located at Kharpu, Madapolan, Sarlisalla and Unapani. Unapani is among the most popular spring in Humla due to its central location in the lower region of the district which is comparatively densely populated. It also provides age-long hydrotherapy service to the sick people from the surrounding areas.

2.1.1 Limi valley hot springs

The hot springs at Kermi, Aita (Takche), Takpachen and Chhurku are located in the Tsam-tso region of Limi valley. This valley is one the unspoiled and pristine area of Humla district and lies just 18 kilometers southeast of Tibet's Lake Mansarovar. It is a sacred lake for both Hindus and Buddhists because of its extraordinary highland biodiversity.

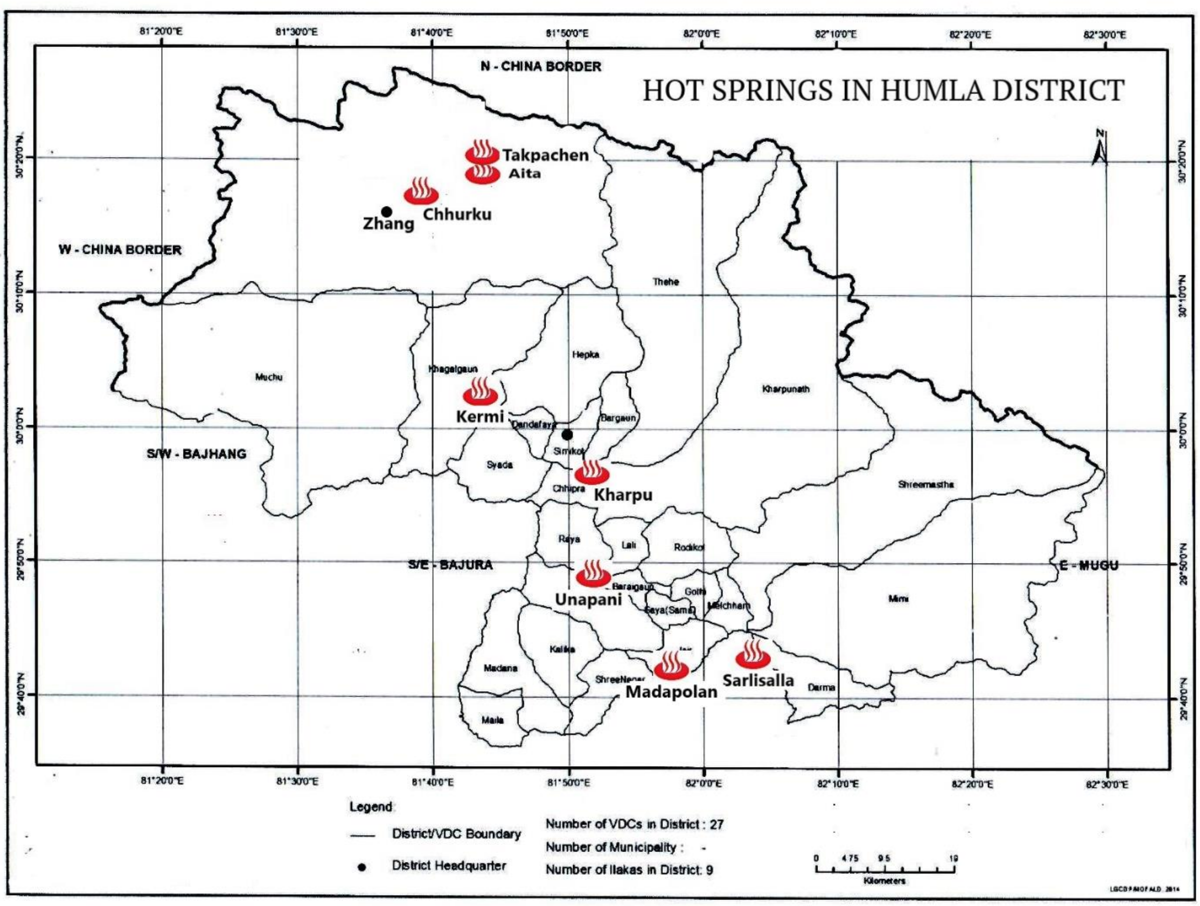

Figure 4: Location of hot springs in Humla district

Kermi hot spring

This spring is located just about 10 minutes' walk from Kermi village. Its steaming water takes the form of a flowing river with a source temperature of 95 ºC. This hot spring represents Nepal's top thermal energy resource in terms of temperature and flow rate. In spite of this, the hot spring is still out of the tourist guide's bookmark for a visit.

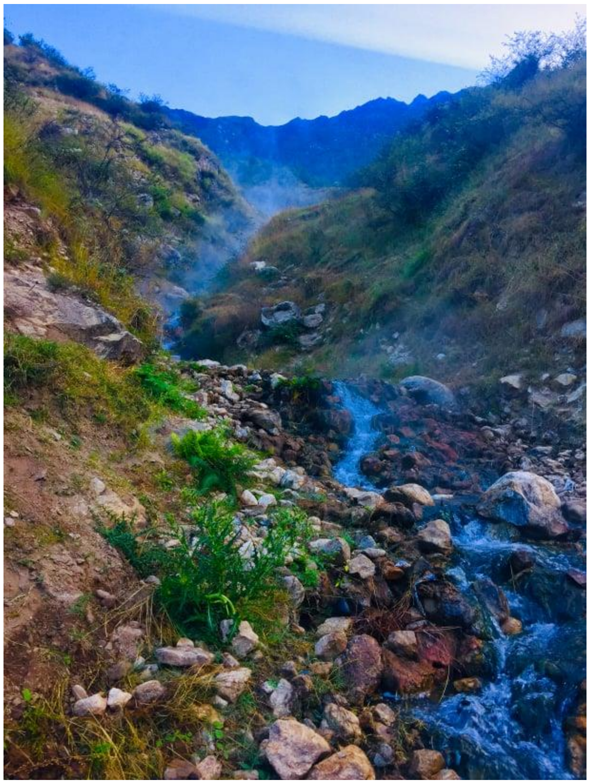

Figure 5: Kermi hot spring (Humla)

Figure 6 : Water mill using spring waterfall (Humla)

The hot spring water has been used for irrigating farmland, mainly wheat, buckwheat and rice by mixing with cold river water since long. The villagers also use a turbine to crush grains by using the hot waterfall (Fig. 6). The water thus emitted again is directed to the source of a water that falls to the bank of Karnali River where it is used to run a turbine to generate electricity for Kermi village.

Aita hot spring - This spring is located north-east of Tumling Bazar near Thungling village. It is also known as Takche hot spring. Three hot spring sources have been identified on the bank of Limi River with a temperature ranging between 30 and 35 ºC. No infrastructure has been built up so far although a foot trail has been constructed from a resort 8-10 minutes' walk down.

Takpachen hot spring – This spring with a temperature between 48 and 55 ºC lies on the other side of Takche spring across the Limi River. No infrastructure exists in the spring area and the spring water is used by the locals only for bathing and laundering.

In 2022, the Government of Nepal listed Limi village as the only Himalayan mountain village. Accordingly, the government is investing for infrastructures to attract people for visiting Lake Mansarovar. The hot springs at Aita and Takpachen in this village hold high prospect to support tourism activity.

Chhurku hot spring- This spring lies half an hour walk north - west of Zhang (Dzang) village, high (4000m +) up in the Limi valley. People can enjoy a good wash at the spring outlet itself. A shower tent is erected for everyone to use free of charge.

2.2 East Rukum district

This district has 5 hot springs in Putha Uttarghanga Rural Municipality, namely Jarlung, Ranma, Dimurgaira, Maikot and Okhma. Sisne Rural Municipality has Dhaune and Pokhara hot springs. Jodu, Khara, Rala, Pelma and Birgum.

Figure 7: Dimurgaira hot spring (East Rukum)

Figure 8: Dhaune hot spring, Sisne (East Rukum)

Figure 9: Sarlisalla hot spring (Humla)

Figure 10: Unapani hot spring (Humla) (source: Rajan Raut, gorkhapatraonline.com 3 March 2021

2.3 Infrastructure development in hot spring sites:

The last three years period saw a significant built up of infrastructures in a number of hot spring sites of Nepal, mostly with the supported by the local communities and to some extent by the provincial government.

Better infrastructure at Chame hot spring Manang district with roof, swimming pool and other facilities have attracted increased number of local and tourists from dawn to dusk. The pools receive high volume of hot water during monsoon period (July – August) when the groundwater is highly recharged.

Figure 11: Hot spring at Chame (Manang)

Figure 12: Chilime – Sanjen hot spring (Rasuwa)

The Chilime hot spring in the Sanjen La valley is one of the prominent springs of Nepal which suffers periodic obstruction in the flow. Each major earthquakes in the area either shuts or opens the hot water discharge, affecting the livelihood of the people relying on hotel businesses. This site has been the source of attracting a large number of mountaineers in the Sanjen La mountain trekking route.

Nundhaki hot spring at Sankhuwasabha district is the only prominent spring found in eastern Nepal. It has a discharge of 140 l/s, making it one of the few hot spring sites with high flow. The water is however tepid and the temperature in winter reaches 30 ºC. This is also a site where the local community has been able to raise substantial fund from the Nepalese diaspora in South Korea, Malaysia, Hong Kong and Singapore. Its good infrastructure is attracting a large number of pilgrimages. Two swimming pools have been constructed in 2022 that utilizes the spring water directly, without any pipes carrying hot water to heat the pool water.

Figure 13: Nundhaki hot spring (Sankhuwasabha) **Figure 14: Nundhaki spring swimming pool**

As in the past, Singa hot spring in Myagdi district has remained the most prominent hot spring sites in Nepal. During the peak period, approximately 1200 to 1500 people come daily. The pool is packed with more than a hundred people at one time with males and females taking turns alternatively. Two more pools have been constructed for people who are willing to take a dip in a more relaxing environment, but at a higher entry fee. Hot water is supplied to these pools by pumping hot spring water emerging on the banks of Myagdi River.

The Singa Hot Spring Management Committee has established a Natural Spring Water Therapy Centre in 2021 with ten million rupees support from the provincial government and the fund raised by the committee from its visitors. The Center aims to impart acupuncture, yoga therapy, physiotherapy, massage therapy and dry therapy services. It aims to employ a minimum of fifteen trained health professionals.

Figure 15: Aerial view of Singa hot spring site (Myagdi) **Figure 16: New settlement area in Singa site (Myagdi)**

3. RENEWABLE ENERGY SITUATION IN NEPAL

Nepal's energy scenario has not changed during the last three years. It is still dominated by the traditional sources of firewood for cooking, agriculture residues, and livestock residues (mainly cow dung cake). However, its contribution to the total energy consumption has slowly decreased from 77.6 % in 2014/15 to 68.63 % in March 2021. This gap is mainly filled by the increase of share from the commercial sources (petrol, coal) and electricity. Contribution from these sources increased from 19.99% to 28.18 % in the past seven year's period.

Figure 17: Recently developed Upper Singa village

Figure 17: Aerial view of Darmija hot spring

As of mid-March of fiscal year 2020/21, the share of conventional, commercial and renewable energy consumption to total energy consumption has been 68.6%, 28.2% and 3.2%, respectively – almost the same picture of the previous year (Fig. 18).

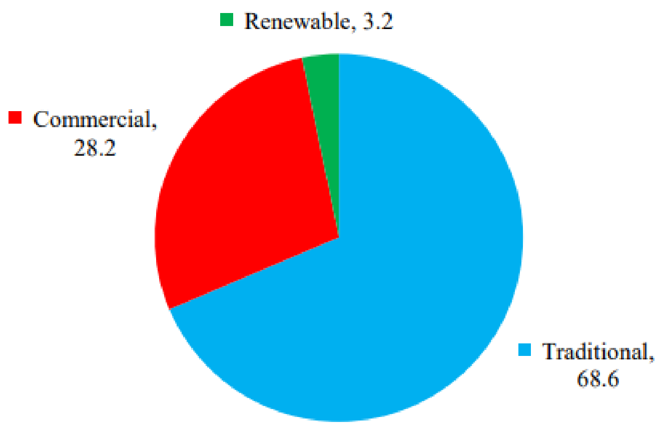

Figure 18: Status of energy consumption as of mid-March 2020/21 (in percent)

(Source: Ministry of Energy, Water Resources and Irrigation, 2021)

As of mid-March of fiscal year 2020/21, 250 kilowatts of electricity has been generated from solar and wind energy, up from 50 kilowatts in the previous year.

3.1 Institutions involved in renewable energy

The Water and Energy Commission (WEC) was formed in 1975 to assist the government of Nepal and its different ministries relating to water resources as well as other agencies in the formulation of policies and planning of water and energy projects. It has sponsored a geothermal project in Nepal for the first time in 2023. The project aims to identify hot spring sources and prepare plans for geo-tourism development in potential hot spring sources.

The Alternate Energy Promotion Center (AEPC) under the Ministry of Energy, Water Resources, and Irrigation is the lead agency and the national focal point to promote renewable energies in Nepal. Currently, AEPC is transitioning from an implementing agency that provides services like subsidies directly, to a support agency that enables provincial and local governments to promote and implement renewable energy technologies. It has been focusing on promoting the use of solar PV technology, solar thermal energy, biomass, wind energy, and mini/micro hydro technology. In 2020, it embraced geothermal energy by sponsoring a feasibility study on the potential of geothermal energy in Nepal. No further actions have been taken since then regarding the implementation of geothermal works.

Central Renewable Energy Fund (CREF), the financial mechanism of the Alternative Energy Promotion Centre (AEPC), has established a Viability Gap Funding based Sustainable Energy Challenge Fund (SECF) in 2022 with funding support from UK-Aid. SECF provides financial and technical assistance to distributed renewable energy (DRE) projects to ensure their financial viability and sustainable operation. However, it is still limited to developing concept notes of potential DRE projects, up to 1 MW in installed capacity, with no regard for geothermal direct-use projects.

Institutions like the National Academy of Science and Technology, Research Centre of Applied science and Technology (Tribhuvan University), and Centre for Alternate Energy (Tribhuvan University), conduct renewable energy research in Nepal. However, none of these conduct research in geothermal energy. The Department of Mines and Geology conducts limited studies on the geology of geothermal sites in Nepal. In 2021, Energy Systems and Technology Research Laboratory (ESTRL) was established under the School of Engineering, Kathmandu University. It plans to embrace research and development in geothermal energy.

4. SOME STUDIES IN THE APPLICATION OF GEOTHERMAL ENERGY

4.1 Electricity generation

A study was also conducted in 2018 (not reported earlier) in a bid to find if it is technically and economically feasible to generate electricity from the available temperature at Bhurung Tatopani (hot spring), Myagdi district of Nepal. It experimented on the stand-alone hybrid solar – geothermal Organic Ranking Cycle (ORC) technology for power generation from this site with the hot spring temperature of 69.7 °C. When this water was fed into the solar collector, the temperature reached 99 ºC. The simulation result of the study conducted with two different working fluids showed that these fluids behave differently when the temperature of the heat source was changed from 70ºC to 120ºC.

For both cases, LCOE was 0.38 USD/kWh. The study concluded that the stand-alone hybrid solar- geothermal ORC system is feasible for power generation and is economically viable. Field application of the technology is yet to follow.

The Alternate Energy Promotion Center (AEPC) sponsored a feasibility study to generate electricity from the Paudwar hot spring which has a surface temperature of 66.2°C and a mass flow rate of 6.48 kg/s. The simulation used the R227ea as an organic fluid in the closed loop system. The study recommended using the spring source by applying the ORC system under a scenario, where the discounted payback period is 24.06 years and the Levelized Cost of Electricity (LCOE) is 0.074 USD/kWh, about five-fold less than the Bhurung hot spring, but with a much longer payback period.

4.2 Industrial and geo-cooling studies

Even though Nepal lags far behind in the utilization of geothermal water for industrial applications, a modest beginning has been made in studying its potential in this direction. For instance, realizing the fact that thermophilic bacteria can produce industrially important enzymes, a study was carried out for enzymatic screening and molecular characterization of thermophilic bacterial strains that were isolated from a hot spring located at Bhurung, Myagdi district of Nepal. It revealed different thermostable extracellular enzymatic activity of bacterial strains isolated from the spring water. The study of isolates confirmed that the isolated Bacillus sp. is a true thermophile and could be a source of various thermostable exozymes which can be exploited for pharmaceutical and industrial applications such as leather, food, and waste processing.

Likewise, a study on the design and analysis of geothermal cooling system has been conducted at Aaurahi, Mahottari district in the Siwalik (Terai) Region of Nepal. The geothermal cooling system design was found to be much more efficient than a traditional air-cooled cooling system having a theoretical coefficient of performance (COP) of around 6.77 and an experimental coefficient of performance of around 4.63. This system was also found to produce maximum performance when the difference between the inlet and outlet of water temperature in the condenser is 9.5°C –10.5°C. The cooling system was also found to be economically feasible when used for more than 5 hours per day through incremental analysis.

5. POPULARIZATION ACTIVITIES

Recent technological advances have made it possible to advertise hot springs in remote parts of Nepal on social media like YouTube and TikTok. This is, however, limited to Singa hot spring (Myagdi district), Kodari hot spring (Sindhupalchowk district), Nundhaki hot spring (Sankhuwasabha district), Dimurgaira hot spring (East Rukum district), and Chilime hot spring (Rasuwa district) only. In a bid to attract national and international visitors at a faster rate, Nepal had planned to observe Tourism Year 2020. Even though the plan could not be launched due to the spread of Covid-19, the initial campaign itself has been able to develop a sense among the local people to popularize hot springs in the local publications. This has prompted the locals to exert pressure on the provincial governments to invest on the infrastructural development in the hot spring sites to boost tourism industry and utilize hot springs for health benefits. However, direct applications of hot water for other uses have not yet been realized by the federal and provincial governments.

Table 2 : Utilization of geothermal energy for direct heat as of 31 December 2021 (other than heat pumps)

Locality	Type	Maximum Utilization			Capacity	Annual Utilization		
		Flow Rate (kg/s)	Temperature °C		(MWt)	Average Flow	Energy	Capacity Factor
			Inlet	Outlet		(kg/s)	(TJ/yr)	Number
Tabopan - Sribagad	B	1.1	71	36	0.161	0.7	3.232	0.636
Sina Tatopani	B	0.8	30	25	0.017	0.6	0.396	0.75
Dethala - Chameliya	B	0.35	32	25	0.010	0.3	0.277	0.857
Tapoban - Bauligad	B	0.3	31	28	0.004	0.3	0.119	0.75
Dhanchauri–Luma	B	0.8	24.5	18	0.022	0.6	0.514	0.75
Tilanadi	B	3	42	34	0.100	2.5	2.638	0.833
Kermi	B	60	94	75	4.770	30	75.183	0.5
Kharpu	B	3.5	35	33	0.029	3	0.791	0.857
Lamchhara - Jair	B	0.9	32	25	0.026	0.8	0.739	0.889
Unapani	B	4	40	35	0.084	3.5	2.308	0.875
Purumaru	B	3.5	40	36	0.059	3	1.583	0.857
Soru - Jima Kulaha	B	3.6	40	35	0.075	3.2	2.110	0.889
Dimmurgaira	M	3.4	47	40	0.100	3	2.770	0.882
Rihar	B	1.5	33	25	0.050	1.2	1.266	0.8
Surai Khola	B	3.8	37	26	0.175	2.7	3.917	0.71
Muktinath	B	3	22	15	0.088	2	1.847	0.666
Jomsom	B	0.07	21	12	0.003	0.05	0.059	0.714
Chame	B	1	55	35	0.084	0.8	2.110	0.8
Bhurung Tatopani	B	1.8	72	30	0.316	1.3	7.202	0.722
Puadwar - Narchyang	B	4.1	66.2	40	0.449	3.5	12.095	0.853
Ratopani - Dhirchyang	B	1.5	54	40	0.088	1.3	2.401	0.866
Sekkar - Bega-Dowa	B	2.5	28	20	0.084	2	2.110	0.8
Jharlang	B	3	29	25	0.050	2.5	1.319	0.833
Chalise	B	2.5	53	30	0.241	2	6.067	0.8
Linjo - Tipling	B	1.2	32	25	0.035	1	0.923	0.833
Sadhu Khola	B	1.4	39	30	0.053	1	1.187	0.714
Jamile	B	0.05	30.6	21	0.002	0.04	0.051	0.8
Jhinu	B	3.2	35	30	0.067	3	1.979	0.937
Kharpani	B	0.4	49	30	0.032	0.3	0.752	0.75
Machhapuchhre base camp	B	2.2	64	31	0.304	1	4.353	0.454
Mayangdi	B	2	40	30	0.084	1.7	2.242	0.85
Singha Tatopani	B	11	54	35	0.874	9	22.555	0.818

Bhulbhulekhar	B	1.2	34	27	0.035	0.8	0.739	0.666
Bahundanda		2.8	95	35	0.703	2.7	21.368	0.964
Setikhila		0.2	44	37	0.006	0.15	0.138	0.75
Chilime	B	8	55	35	0.669	6	15.828	0.75
Syabri Besi	B	0.35	34	28	0.009	0.3	0.237	0.857
Pargang	B	5	49	30	0.397	4	10.024	0.8
Kodari	B	32	42	35	0.937	4.8	4.432	0.15
TOTAL					**11.291**		**219.862**	

Table 3 : Summary table of geothermal direct heat uses as of 31 December 2021

Use	**Installed Capacity (MWt)**	**Annual Energy Use (TJ/yr)**	**Capacity Factor**
Individual Space Heating			
District Heating			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying			
Industrial Process Heat			
Snow Melting			
Bathing and Swimming	11.291	219.862	0.769
Other Uses (specify)			
Subtotal	11.291	219.862	0.769
Geothermal Heat Pumps			
TOTAL	11.291	219.862	0.769 (avg.)

Table 4: Present and planned production of electricity

	Fossil Fuels*		**Hydro**		**Other renewables****		**Total**	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2021	53.41	375	2150.00	7495.93	1.05	2.60	2204.46	7873.53
Under construction in December 2021	n.a.	n.a.	150.00	522.97	n.a.	n.a.	150.00	522.97
Funds committed, but not yet under construction in December 2021	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Estimated total projected use by 2022	62.00	435.31	2637.10	9194.20	1.05	2.60	2700.15	9632.11

** 801 kW electricity from micro and small hydro projects, 250 kW from solar and wind.

Table 5: Total investments in geothermal in (2021) US$

Period	Research & Development Including Surface Exploration. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.02	0	0.01	0	100	0
2000-2004	0	0	0.03	0	100	0
2005-2009	0	0	0.05	0	100	0
2010-2014	0	0	0.06	0	100	0
2015-2019	0	0	0.14	0	100	0
2020-2022	0.16	0	0.2	0	25	75

A book entitled ‘Hot springs in Nepal: Health benefits and geothermal applications’ have been published by Springer Nature in 2022. The book, first of its kind, has exposed dozens of hidden hot springs and explained how the hot water in Nepal can be tapped for direct use and treatment of various diseases.

The book also explores Kermi hot spring in the Humla district which appears in the form of a river with source temperature at 95 °C. This huge resource is currently used only in a fraction by the locals for bathing and laundering, irrigation and running a water mill for processing locally produced grains, and diverting to mix with a local waterfall to generate electricity which has been utilized for the village’s energy needs. Under-utilization of this has proven as a mockery to the natural boon of the district. The gentle slope of the area starting from the source can prove as an excellent example to the outside world as well to display the cascaded use of geothermal resources.

6. CONCLUSIONS AND FUTURE ACTIONS IN GEOTHERMAL DEVELOPMENT

Advertising activities through various media are significantly boosting awareness of local people to utilize hot spring sites. People in Singa, Jhinu, Bhurung, Kodari, and Chilime thermal sites have realized the strong link between hot springs and tourism. Due to the overwhelming number of visitors to Singa hot spring, a new settlement has been created along with the expansion of hotel and lodging facilities. However, the spread of Covid - 19 led to the closure of hot springs, resulting in a total collapse of these businesses. Likewise, the fate of local businessmen is highly determined by the Chilime hot spring in Sanje La area. Its closure due to Covid - 19 and other natural reasons at different times has frequently affected the local businesses.

Pressure is constantly built up on the local governments and communities to develop infrastructures in the hot spring sites. Accordingly, a handful of hot spring sites have received financial contributions from the provincial government. Governmental, non-governmental organizations, and private agencies dealing with tourism businesses should play a significant role in promoting hot spring sites as recreational and spa centers. It can be done by incorporating hot springs in and around the trekking areas in their tour package. Even though the Water and Energy Commission has initiated a study to develop plans for geo-tourism development, implementation of the recommendations will have a long way to go.

The Alternate Energy Promotion Center (AEPC) has been promoting other alternative energies in Nepal with financial support from donor agencies. It is currently inviting applications for Distributed Renewable Energy (DRE) projects developed in a Public Private Partnership model in partnership with local and provincial governments. These projects are limited to generating electricity alone. Various subsidy plans are in place for other renewable energy sectors excluding geothermal, as those plans are intended to support the local government’s programs. Neither local municipal governments nor the private sector have ventured into any geothermal projects, due to the lack of technical expertise and funding for direct uses of geothermal energy.

Corruption by high and middle level political leaders has become a common phenomenon in Nepal over the past three decades. It has resulted in critical budgetary problems for the federal and provincial governments to initiate new projects in almost all sectors of development. However, it is still possible for the local community to utilize its labor and limited resources to improve access roads to the hot spring sites and create sizable infrastructures to attract and extend the tourists' stay in their area.

While private agencies have critical roles to play in direct utilization, they do not get involved unless there is a guarantee of profit. Innovative investment policies need to be developed to stimulate the private sector by providing tax exemptions and subsidies. technical support and elimination of administrative hurdles at the early stages. As the production of hydroelectricity has exceeded demand in recent years, it has become necessary for the energy planners to rise above conventional wisdom that has been built up over the past four or five decades to view geothermal energy from electricity generation standpoint alone, to focus on other direct uses, including tourism, spa development, and the application of geothermal heat pumps, aquaculture, greenhouse farming, drying of agricultural products, etc.

Chemical data provide a blueprint for the potential use of geothermal water, information about the benefits and risks associated with spa development. Such data also help to estimate the subsurface temperature of geothermal water and identify locations where underground water at higher temperatures can be drilled for various direct uses as well as for electricity generation. Most of the existing chemical data dates to decades and a vast number of newly identified geothermal springs have not undergone any scientific studies including chemical analysis. The Research and Development (R&D) units of the Nepal Academy of Science and Technology, Department of Mines and Geology, Tribhuvan University and Kathmandu University should conduct chemical analyses, processing of data, geophysical mapping, groundwater temperature logging, reservoir estimation of thermal springs using modern techniques of exploration such as fluid inclusion survey and acoustic emission method. Such information help the energy planners in their decision making process as well as devising suitable programs at various geothermal sites.

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