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Geothermal Energy Update of Nepal

Mahendra Ranjit

Research Centre for Applied Science and Technology, Kirtipur, Kathmandu, Nepal.

mranjit11@yahoo.com

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ABSTRACT

After more than twelve years' insurgency, Nepal witnessed a major political change, with the abolishment of 250 years old monarchial system. Evidently, the internal conflict had a long-term adverse impact on the implementation of all development projects including renewable energy. The unstable political situation also forced the country to satisfy with a three year interim development plan (2008-2011) instead of a normal 'five-year plan'. Accumulation of technical and other problems led the country to declare 'national energy crises in late 2008 for the first time in the country's history, leading its major cities to excessive electric load shedding and a virtual standstill in the industrial sector. While the implementation of a number of ambitious and moderate hydroelectric projects is still underway, it will take considerable time before the nation can feel relaxed in the energy sector. Following the old tradition, the government made no delay in coming up with emergency renewable energy plan to fulfill the immediate energy demand, focusing on tapping wind energy and promoting private sector for small scale hydroelectricity generation.

The interim plan of Nepal emphasizes the development and promotion of the already implemented renewable energy sources like biogas, wind energy, solar energy, improved cook stoves, solar electrical systems, micro-hydropower schemes etc. Like in the past, geothermal energy has not received due consideration. Absence of roads linking many geothermal areas in the remote parts of the country had remained a major bottleneck in the execution of geothermal activity.

In spite of the government's least investment, construction of road in the rural areas took place at a very fast pace with the initiative and funding of local communities during the period 2005 - 2009. Taking advantage of the much improved rural road network, availability of new technologies to exploit low temperature geothermal water for electricity generation, creation of basic geochemical information and the importance of utilizing low temperature water for direct application, an agreement was signed in early 2008 between the Glitnir Bank (an Iceland- based Nordic development bank) and Noida, India-based LNJ Bhilwara Group to set up geothermal plants in Nepal and India. The location and detail plans of geothermal activity for Nepal are still under formulation stage. However, it is most likely to be executed in the northern mountainous belt of Nepal along the same latitude in India where the program has been finalized. Discussions are being held with a number of potential Nepali partners to invest in the project. Properly initiated and implemented, this will herald the beginning of a new era in the geothermal development in Nepal. This venture will also serve as seed pilot project(s) to attract private investors to extend the activity to other areas of Nepal. Mechanisms to promote activities at the private level are already in place. The National Rural Energy Strategy of Nepal ensures a long-term sustainability of the renewable energy sector based on implementation of programs by the private sector (including NGOs), easy and long- term financing of programs by the financial sector and through government subsidy, capacity building of the private and financial sectors, among other things. The government of Nepal has also promulgated an ordinance in the early 2009 to set up an Investment Board to attract private entrepreneurs in the energy sector including 'renewable'.

1. INTRODUCTION

Flanked by India in the South and the Tibetan Autonomous Region of China in the North, Nepal is a landlocked country located in between the latitude 260 22' N to 300 27' North and longitude 800 4' E to 880 12' East and elevation ranges from 90 to 8848 meters. The average length is 885 km. east to west and average breadth is about 193 km. north to south. The high Himalayas stand in the northern belt, including the highest peak in the world, Mount Everest (8,850 m). Along its Southern border is the flat and fertile Terai region. The central hills have terraced cultivation and swiftly flowing mountain rivers. Eight of the world's highest peaks including Mount Everest are in Nepal.

Nepal's population is about 25.88 million, with an estimated growth rate of 2.27 percent. About 7.3 percent of the population lives in the mountains, 44.2 percent in the hills and 48.5 percent in the Terai.

1.1 Government Setting

Nepal witnessed a dramatic political change in 2006 when the decade long insurgency culminated into a peaceful People's Movement in 2006 against the autocratic royal regime, and the dissolved parliament was restored. The parliament announced itself as the supreme state authority until a new constitutional arrangement is put in place. Under the provision of the interim constitution, a jumbo Constituent Assembly comprising 601 members was formed through election, among them a few from party nomination. The Constituent Assembly declared Nepal as the Federal Democratic Republic in 2008 with the formal abolishment of 250 years old monarchial system. The President acts as the Head of the State and the Prime Minister is vested with the executive power. Currently, the Constituent Assembly is functioning both as the legislature parliament representing the Upper and the Lower Houses. The Assembly is currently preparing the new constitution of Nepal to be completed in 2009.

In the absence of a clear majority of any political party in the Assembly, coalition governments are running the country. The first such government failed eight months after its formation while the second government is also running with great difficulty.

Supreme Court acts as court of appeal. The country is divided into 5 Development regions, 14 Zones, 75 Districts, 3995 village development committees and 36 municipalities.

The new constitution is expected to come up with a thoroughly revised structure.

1.2 Policies and interests

1.2.1 General policies

In this transition stage, the government has formulated a 3 year Interim Plan (2008-2011) in place of a regular five year development plan. The main objective of the Plan is to reduce poverty and existing unemployment as well as to establish sustainable peace.

The main strategies of the plan are to:

1. **Place** special emphasis to relief operation and social rehabilitation of individuals or groups affected by conflict, rural infrastructure reconstruction, investment plan for roads, rehabilitate and reintegrate physical, economic and social infrastructure s damaged due to conflict

2. **Create** and expand employment opportunities through training and application of appropriate technology

3. **Increase** pro-people and broad-based economic growth by expanding manufacturing and service sector and making the private-public sector more effective

4. **Promote** good governance and effective service delivery by involving the private sector and civil society including NGOs and community organizations

5. **Increase** investment in physical infrastructure, particularly the roads connecting district headquarters and north-south corridors and take initiative for mega hydro-electric projects

6. **Adopt** an inclusive development process by involving socially excluded groups, indigenous people, dalit (deprived group), Madheshi / Terai people, women, deprived, people with disability and extremely poor people covering those living in remote geographical areas.

The last strategy mentioned above is the most important and challenging one to bring about major socio-economic transformation in the country. Special provision has been made for its inclusion in the Interim Constitution in the light of People's Movement. Its implementation has been very encouraging despite pressure from the powerful elite group.

As always, the priority sectors of the Interim Plan include agriculture, tourism, infrastructure development of roads, irrigation and communication, electricity, education and health.

The ambitious Interim Plan projects the annual average economic growth rate to 5.5 percent, which will increase per capita income by 3.3 percent and employment by 3.5 percent on an average annually. The percentage of population living below the poverty line is projected to be 24 percent. The impact of current global recession in achieving these quantitative objectives remains to be seen.

1.2.2 Alternate energy related policies and interests

The Energy Sector Assistance Programme (ESAP) that started its Phase I program during 1999-2006 with the assistance of Denmark and Norway is extending the Phase II program for the period 2007-11. The program has three main components:

i. Institutional Strengthening of Rural energy Sector to promote coherence and coordination of policies for rural energy supply by:

- developing a coherent policy for rural energy supply
- providing support for institutional strengthening of government institutions involved in rural energy supply, donor coordination and harmonization with a view to developing a SWAp

ii. Rural energy Investmen t- Rural Energy Fund to promote access to and affordability of renewable energy solutions in rural areas. A Rural Energy Fund (REF) will be created and additional resources mobilized to build capacity in the evaluation and monitoring of rural energy solutions. Local financial institutions will be involved to promote access to private loan financing for renewable rural energy solutions.

iii. Technical Assistance: to provide technical support for the development and implementation of renewable rural energy solutions that either receives financing from the REF or can be financed by the consumers directly. The programme will focus on Biomass energy (Improved cooking stoves, gassifiers), Solar Energy (Solar home systems, solar powered lamps), Mini Grid electrification (small hydropower installations of up to 1 MW that can electrify villages of up to 1,000 households).

2. GEOLOGY BACKGROUND

2.1 Nepal occupies the central sector of Himalayan arc covering nearly one third of the 2400 km long Himalayan range. The country can be divided into the five major tectonic zones separated from each other by the thrust faults. The southernmost fault, the Main Frontal Thrust (MFT) separates the Sub-Himalayan (Siwalik) Zone from Gangetic Plains. The Main Boundary Thrust (MBT) separates the Lesser Himalayan Zone from Siwalik whereas the Main Central Thrust (MCT) separates the Higher Himalayan Zone from the Lesser Himalayan Zone.

Gangetic Plain (Terai Zone): The Nepalese portion Gangetic Plain extends from the Indian Shield in the South to the Sub-Himalayan (Siwalik) Zone to the North. The plain is in less than 200 meters above sea level and usually has thick (nearly 1500 m) alluvial sediments. The alluvial sediments contain mainly boulder, gravel, silt and clay. The width of Terai Zone varies from 10 to 50 km and forms a nearly continuous belt from east to west. Terai Zone is a foreland basin and has sediment originated from peaks of Northern part. To the north, this zone is separated by an active thrust system called as the Main Frontal Thrust (MFT) with Siwalik.

Northern Terai (Bhabar Zone) is mainly composed of boulders, pebbles, cobbles and coarse sand derived from the rocks of Siwalik and Lesser Himalaya. Bhabhar Zone acts as a recharge zone for the groundwater of Terai. *Middle Terai (Marshy) Zone* is a narrow zone of about 10-12 km wide and lying between the Northern Terai Zone and the Southern Terai Zone. This zone is characterized by pebbly and brown to grey colored unconsolidated sandy sediments with few clay partings. *Southern Terai Zone* is the southern most part of Terai up to Nepal-India border and also continues into India. This zone consists of main sediments of Gangetic Plain. Basically, sand, silt and clay are the main sediments of this zone.

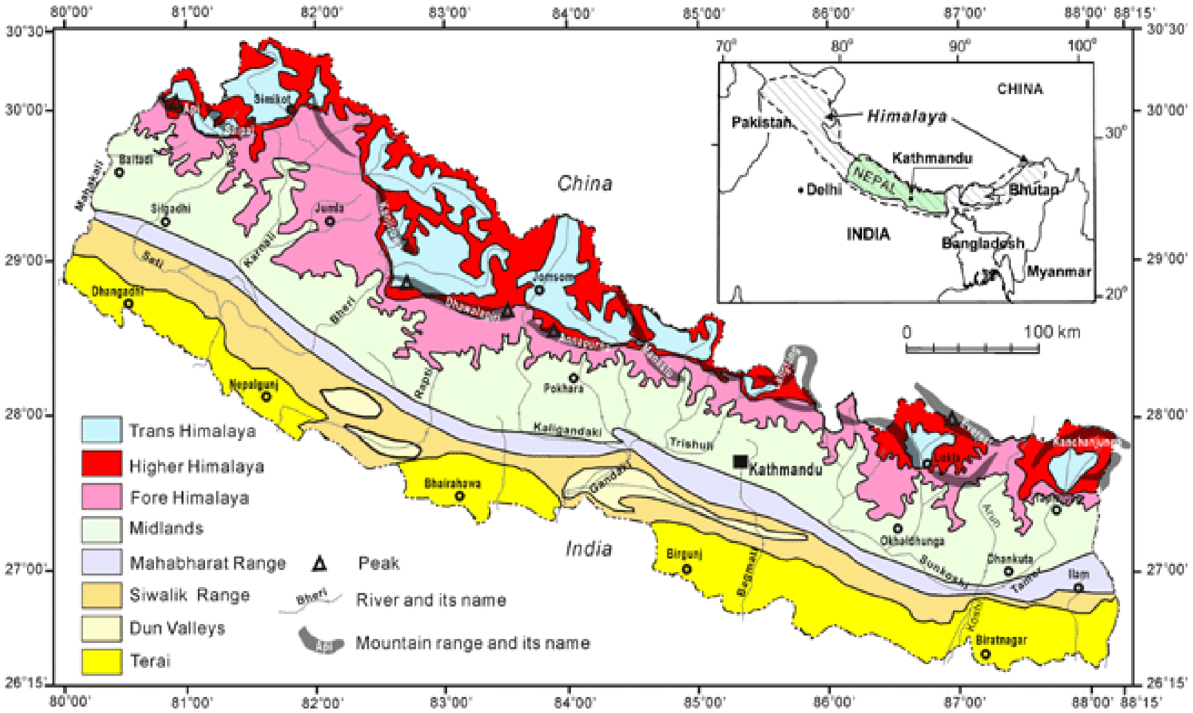

Fig 1: Physiography of the Nepal Himalaya (after Dahal and Hasegawa, 2008)

Sub-Himalayan (Siwalik) Zone: This zone is delimited on the south by the Main Frontal Thrust (MFT) and on the north by the Main Boundary Thrust (MBT). It mainly consists of fluvial deposits of the Neogene age and extends all along the Himalaya forming the southernmost hill range with width of 8 to 50 km. The Lesser Himalayan rocks thrust southward over the rocks of Siwalik along the MBT. This zone is rich with fossils of plants, pisces, reptiles and mammals.

Lower Siwalik region consists of irregularly laminated beds of fine grained greenish sandstone and siltstone with mudstone. The alternating mudstone beds are thickly bedded and are variegated, red, purple, and brown coloured. Middle Siwalik region consists of medium to coarse grained salt-and-pepper sandstones inter-bedded with mudstone. In Middle Siwalik the sandstone beds have thickness mostly ranging from 1 m to 45 m. *Upper Siwalik* is composed of conglomerate and boulder beds as well as subordinately sand and silt beds. The mudstone beds are massive and irregular containing many invertebrate fossils.

Lesser Himalayan Zone: This zone is bounded to the north by the Main Central Thrust (MCT) and to the south by Main Boundary Thrust (MBT). MBT can be traced out in entire Nepal Himalaya. The rocks of Lesser Himalayan Zone have been transported southwards in several thrust slices. From east to west, the Lesser Himalayan Zone of Nepal varies in rock type, age, structures, and igneous rock intrusion. The eastern part shows the development of extensive thrust sheets of high grade metamorphic rocks (gneiss and schist) which have moved southwards. The western part is characterized by the reappearance of high-grade metamorphic rocks.

The Higher Himalayan Zone: This Zone mainly consists of huge pile of strongly metamorphosed rocks. It includes the rocks lying north of the Main Central Thrust (MCT) and below the highly fossiliferous Tibetan-Tethys Zone. It consists of an approximately 10 km thick succession of strongly metamorphosed coarse grained rocks extending continuously along the entire length of the country and its width varies from place to place. Granites are found in the upper part of the unit.

The Tibetan-Tethys Zone: The Tibetan-Tethys Zone lies in northern part of the country. It begins from the top of the South Tibetan Detachment System and extends to the north in Tibet. In Nepal, the fossiliferous rocks of the Tibetan-Tethys Zone are well-developed in Mustang, Manang and Dolpa area. In eastern part, amount of exposure of the Tibetan Tethys Zone is almost negligible and found only in top of the Mount Everest. Most of the other Great Himalayan peaks of Nepal such as Manaslu, Annapurna, and Dhaulagiri have rocks of Tibetan-Tethys Zone. This zone is composed of sedimentary rocks such as shale, limestone, and sandstone, ranging in age from Cambrian to Eocene. This zone in some area is found as continuous deposits of Higher Himalayan Zone without normal fault.

3. GEOTHERMAL RESOURCES

3.1 During this update period, about a dozen of thermal locations have been identified at Dugnam, Ratopani, Mahavir and Narchyang in Myagdi and Mustang districts located between latitude 83.3° and 83.7° and longitude between 28.2° and 29.8°. Normal temperature ranges between 28° C and 38° C. The other thermal manifestations are located at Muktinath (3800 m a.s.l.), Mirsa-Seti Khola area (1200 m a.s.l.), Jamile (1500 m a.s.l.), Machhapuchhre Base Camp (800 m a.s.l.), Down Batase (1900 m a.s.l.), Up Batase (2000 m a.s.l.), and Pargang (2600 m a.s.l. and north of Syabrubesi). Preliminary information about these springs are available.

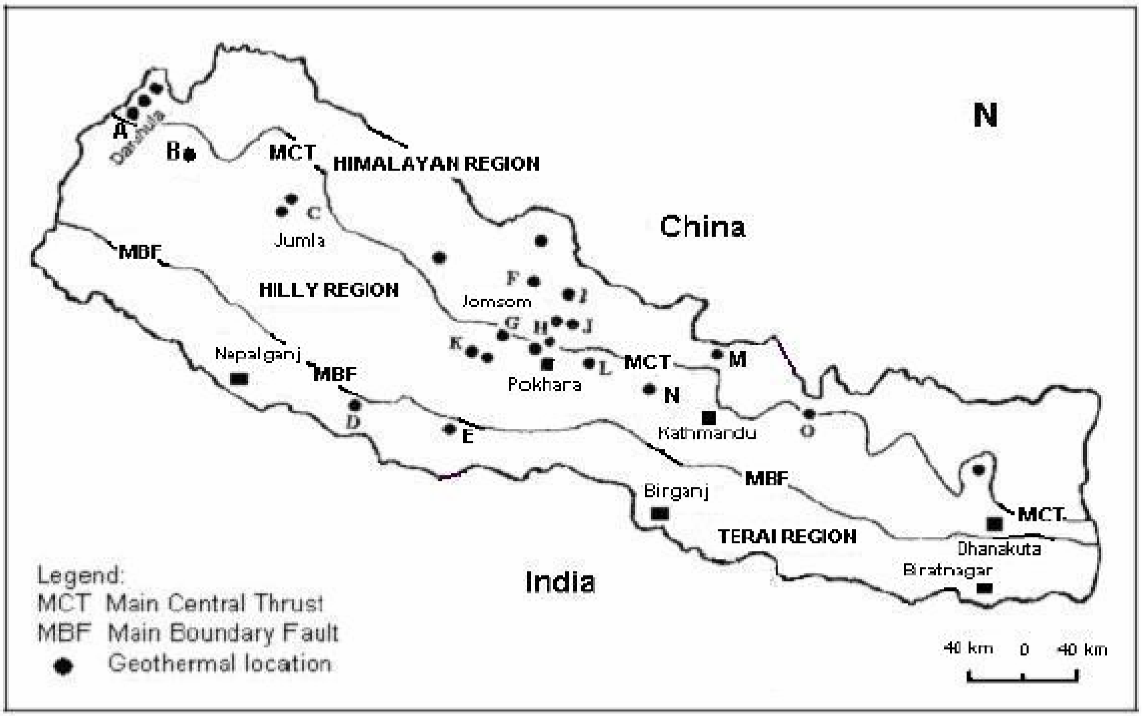

Fig 2: Map of thermal location in Nepal

3.1 Scientific studies:

A number of studies were carried out by the foreign research teams in the Central Nepal during this update period. A detailed study was conducted on the role of hot springs in the Narayani River Basin of central Nepal (area 35,000 sq. km), the major drainage of the Nepal Himalaya and a major tributary to the Ganges. It has been reported that the thermal water in the area yield germanium – silicon (Ge/Si) ratios from 6 to 1000 μ mol/mol, comparable to or higher than ocean heat floor hot springs (< 25 μ mol/mol) and thermal waters from Iceland (9 to 150 μ mol/mol). The high Ge/Si ratios in the hot springs may reflect Rayleigh fractionation as low Se/Si quartz is precipitated. Preliminary estimates in the Marsyangdi River yield a thermal power output rate of 200 MW, comparable with geothermal fields in the Taupo Volcanic Zone and when distributed over the spring affected area, yield a hydrothermal heat flow (160 m W/m^2) comparable to continental heat flow and hydrothermal heat loss in the geothermal belt across Tibet.

In this region, more than four hot springs suggest substantial fluid flow (thermal power: approximately 61 MW) and are proximal to 82 apatite fission-track (AFT) ages.

Hot springs sampled along a 150 km stretch of the Himalayan front near the Main Central Thrust showed that they carry large fluxes of CO2 derived from metamorphic origin. Hot spring fluids are saturated with CO_2, have [DIC] from 1.3 to >100 mmol kg^{-1} and have $\delta^{13}C_{DIC}$ values from −13‰ to +13‰$_{(PDB)}$. Analysis of CO_2 released by decrepitation of fluid inclusions from syn- and postdeformational quartz veins indicate that crustal fluids had $\delta^{13}C$ from −15‰ to +2‰$_{(PDB)}$, consistent with production of CO_2 from both thermal decomposition of organic matter and decarbonation at depth. Modeling of the hot spring fluid compositions indicates that they are strongly egassed. The metamorphic degassing flux of CO_2 in the 32,000 km^2 Narayani basin of the central Himalaya is >1.3 × 10^{10} mol a^{-1}, exceeding the calculated consumption of CO_2 by chemical weathering for the Narayani River basin by a factor of four. The study implies that the net impact of Himalayan orogenesis on the carbonate-silicate geochemical cycle is not large-scale drawdown of CO_2 because the weathering sink is substantially offset or even exceeded by the metamorphic source. The spring fluids within the steeply incised gorges of the central Nepal Himalayan front have total dissolved solids (TDS) up to 7000 mg/L and Na^+, and K^+ typically comprise >50% of the cationic charge, indicating that high-temperature silicate alteration is the dominant source of hot spring alkalinity. HCO_3^- is normally the dominant anion. Sr isotope ratios from the hydrothermal fluids are similar to the range of values found in the host rocks and imply significant fluid-rock interaction with local lithologies.

3.2 Local Efforts:

Geothermal works at this stage has been taking place at a very small scale with the increased participation of local government and the limited financial resources. Increased popularization of geothermal springs has led to more attraction of the visitors. The local people has been able to boost their business and as a result, taken initiative to build road infrastructure with the assistance of local government body. Physical infrastructure development has been given priority. The continuous disruption of electricity (load shedding of up to 16 hours a day) in the urban areas and long term nature of the hydroelectricity generation projects have prompted the people to find fastest and easiest way of getting electricity. Especially at a time when the hydroelectric projects are suffering huge political influence from bilateral and international agencies, their implementation has been much difficult and taking considerably longer time.

Table 1: Geothermal localities and general information

Locality	Symbol	Flow rate (l/s)	Surface temp. (ºC)	Discharge enthalpy (kJ/kg)
Darchula	A			
Sribagar		0.9	73	380
Sina Tatopani		0.8	30	255
Chamaliya		0.3	30	158
Tapoban	B	0.3	31	126
Jumla	C			
Dhanchauri – Luma		0.8	24	448
Tilanadi		1.3	42	464
Riar	D	1.5	33	227
Surai Khola	E	1.7	36	210
Muktinath	F	3	22	211
Jomsom		0.07	16.5	380
Bhurung Tatopani	G	1.8	72	484
Sadhu Khola	H	1.5	68	460
Mirsa – Seti Khola area				332
Jamile		0.05	30.6	n.a.
Kharpani	I	0.4	49	n.a
Machhapuchhre base camp		2.2	64	1020
Mayangdi	J	2	40	376
Down Batase		0.1	44.3	420
Up Batase		0.2	21.5	n.a.
Singha Tatopani	K	6	54	452
Bhulbhulekhar	L	1.2	34	n.a.
Chilime	M	0.9	48	386
Syabri Besi	N	0.4	34	365
Pargang		3.8	49	390
Kodari	O	5.5	42	17

4. PLANS FOR GEOTHERMAL UTILIZATION

The government's alternative energy plan is still broad, and is dependent on foreign financial assistance and loan. Its targets are limited to biomass, solar energy, mini hydroelectricity. Geothermal and wind energy resources are still away from its sight. However, its broad policy to create and mobilize Rural Energy Fund has helped to expand the geothermal energy as well. The National Rural Energy Strategy of Nepal ensures a long-term sustainability of the renewable energy sector based on implementation of programs by the private sector (including NGOs), easy and long- term financing of programs by the financial sector and through government subsidy, capacity building of the private and financial sectors, among other things. The government of Nepal has also promulgated an ordinance in the early 2009 to set up an Investment Board to attract private entrepreneurs in the energy sector including 'renewable'.

This broad vision, even though lacking definite programs, has been one of the factors to attract foreign investors. For instance, Glitnir, the Nordic corporate investment bank, and LNJ Bhilwara Group with operations in India and Nepal has signed a Memorandum of Understanding in late 2007 to collaborate in developing geothermal power plants in India and Nepal. Glitnir will play the role of bringing expertise in the geothermal field and financial structuring of projects related to development of geothermal sources. LNJ Bhilwara Group will play the role of local developer and manager of the project. Glitnir and LNJ Bhilwara Group will work together in developing the business plan and the project. The details of the plan to be implemented in Nepal are still under development. It aims to carry out the plan with the involvement of a local consulting firm and mobilizing local financial resources.

The completion of South – North link highway, particularly Jomsom - Beni area in the central Nepal, during this update period will serve as a landmark in the history of geothermal development in Nepal. Central Nepal has the highest number of geothermal locations in the country. Moreover, the author estimates that there is a large geothermal reservoir in this area. This highway has directly linked a number of geothermal localities in this region while bringing other locations to an extremely closer proximity. The investors and explorers can conduct geothermal related works at a much reduced cost. Another South - North highway linking Surkhet and Jumla will result similar benefits, even though at a lower degree.

The update period witnessed a growing enthusiasm from the foreign private investor for the development of spa in some parts of the country. The convey of message that there exists a large geothermal reservoir in the central Nepal has also drawn attention of some international energy companies to undertake thorough scientific studies before implementing a long term geothermal development program. However, because of the high political instability in the country, plans are difficultly being materialized. The government is preparing a tourism policy which, among other things, includes substantial increase in private investment and harnessing local energy resources. Evidently, in places where hot springs have been a source of tourist attraction, local people have shown keen interest to mobilize local government bodies and expanded physical infrastructure for the utilization of hot spring waters. Even where tourists rarely appear, considerable effort has been made in the infrastructure development through local government and people as a result of the past popularization effort. It is clear that the new tourism policy supplemented by adequate financial support will help to harness geothermal energy resources in the near future.

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Table 2. Utilization of geothermal energy for direct heat (as of 31 December 2009)

Locality	Type	Maximum Utilization			Capacity	Annual Utilization		
		Flow Rate	Temperature (°C)			Ave. Flow	Energy	Capacity
		(kg/s)	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Darchula								
Sribagar	B	0.9	73	35	0.143	0.8	4.010	0.889
Sina Tatopani	B	0.8	30	25	0.017	0.7	0.462	0.875
Chamaliya	B	0.3	30	25	0.006	0.3	0.198	1.000
Tapoban	B	0.3	31	24	0.009	0.3	0.277	1.000
Jumla	B							
Dhanchauri–Luma	B	0.8	24	18	0.020	0.7	0.554	0.875
Tilanadi	B	1.3	42	34	0.044	1.1	1.161	0.846
Riar	B	1.5	33	25	0.050	1.3	1.372	0.866
Surai Khola	B	1.7	36	26	0.071	1.4	1.847	0.823
Muktinath	B	3	22	15	0.088	2.7	2.493	0.900
Jomsom	B	0.07	16.5	12	0.001	0.05	0.030	0.714
Bhurung Tatopani	B/O1	1.8	72	30	0.316	1.3	7.202	0.722
Sadhu Khola	B	1.5	68	30	0.238	1.2	6.015	0.800
Jamile	B	0.05	30.6		0.006	0.04	0.161	0.800
Kharpani	B/O1	0.4	49	30	0.032	0.3	0.752	0.750
Machhapuchhre base camp	B	2.2	64	31	0.304	2	8.705	0.909
Mayangdi	B	2	40	30	0.084	1.7	2.242	0.850
Down Batase	B	0.1	44.3	26	0.008	0.1	0.241	1.000
Up Batase	B	0.2	21.5	15	0.005	0.2	0.171	1.000
Singha Tatopani	B/O2	6	54	30	0.602	5.6	17.727	0.933
Bhulbhulekhar	B	1.2	34	27	0.035	1	0.923	0.833
Chilime	B	0.9	48	35	0.049	0.8	1.372	0.889
Syabri Besi	B/O1	0.4	34	28	0.010	0.3	0.237	0.750
Pargang	B	3.8	49	30	0.302	3	7.518	0.789
Kodari	B	5.5	42	30	0.276	5.1	8.072	0.927
TOTAL					2.717		73.743	0.861

B = Bathing and swimming (including balneology)

O1 = Boiling eggs for restaurants and household use

O2 = Direct drinking to cure for gastroenteritis disease

Table 3. Summary table of geothermal direct heat uses (as of 31 December 2009)

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
Individual Space Heating[4)]			
District Heating [4)]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]			
Snow Melting			
Bathing and Swimming[7)]	2.717	73.743	0.861
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL	2.717	73.743	0.861