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Pilot Project Study for Utilization of Geothermal Energy in North-Western Himalayas

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ABSTRACT

From the north to south, India has seven geothermal provinces. Some of these are in the passive continental margin and some in the active subduction related to tectonics. Some of the potential sites in the north-western Himalaya in India, where geothermal energy can be tapped, are Puga and Chumathang in Jammu and Kashmir, Manikaran and Tattapani in Himachal Pradesh.

An Indo-Norwegian project, with participants from Iceland, Norway and India, aim to set up two pilot demonstration projects in the north-western Himalayas in India. The focus is to demonstrate the utilization of low and medium temperature resources for heating purposes. Two sites in the Himalayan Region have been selected for pilot studies, one for heating of buildings using hot springs available in the area and the other using a ground source heat pump (GSHP). This paper focuses on the first study.

The first pilot project will be set up in the rural area of Chumathang at about 4000 masl, where energy from a natural hot spring will be used for heating two small buildings. In this area, the outside temperature is as low as -16 °C to -20 °C in the winter. The main issues are to design a suitable heating system where a small heat exchanger shall transfer heat between the hot spring and a radiator heating system. From the heat exchanger, the hot water will be distributed to the buildings in a conventional steel piping system. For that, there is a need for two electrical circulation pumps of totally 600 W. This is a challenge due to the limited supply of electricity (max. 3 hours per day) in the area. This means that the pumps need to have electrical supply from renewable energy sources such as solar panels.

Preliminary geological and water sample studies have been performed in the area. The water sample studies indicate that the spring water is suitable for heating and not aggressive for the heat exchanger. Magneto telluric (M-T) surveys have been performed to evaluate the size of the hot spring area.

1. INTRODUCTION

Geothermal energy is a clean and renewable energy source. The source is usually:

- residual heat from the earth´s origin,
- natural radioactivity (some minerals containing uranium, thorium or potassium) where decomposition produces heat or
- heat flow from the core of the Earth that has a high temperature.

The heat from the earth will not only warm up the ground, but also the groundwater. Dependent on the temperature of the resource, different methods are used for utilization of geothermal energy, see Figure 1.

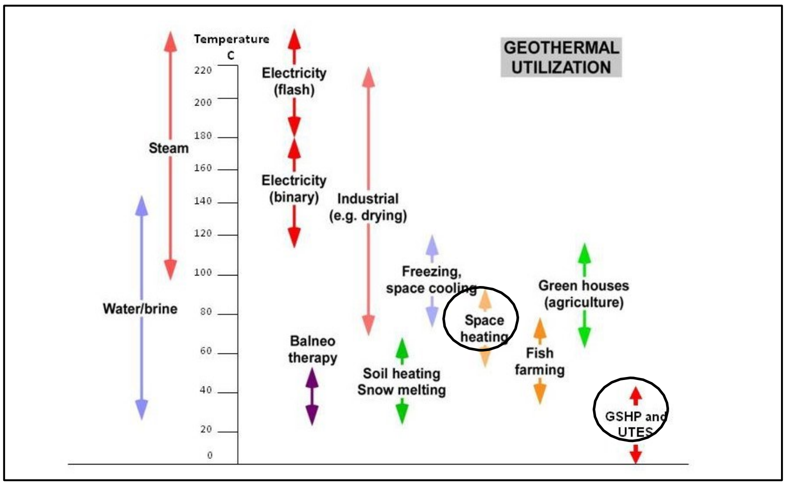

Figure 1: Different methods for utilization of geothermal energy dependent on source temperature

The project consists of two pilot projects for direct use of low-temperature geothermal resources: space heating by extracting heat from a hot spring in a heat exchanger and space heating using a Ground Source Heat Pump (GSHP). The two black circles in Figure 1 show these methods vs the temperature of the resource. This paper discusses only the space-heating project. No pilot projects of these types have so far been built in India.

2. GEOTHERMAL ENERGY IN INDIA

From the north to south, India has seven geothermal provinces (Chandrasekharam, 2005), see Figure 2. Some of them are in the passive continental margin and some in the active subduction related to tectonics. Some of the potential fields in the north-western Himalaya in India where geothermal energy can be tapped are Puga and Chumathang in Jammu and Kashmir, Manikaran and Tattapani in Himachal Pradesh, see Figures 2 and 3. Other place in India are Chhattisgarh, Jharkhand, Uttarakhand, Maharashtra and Gujarat. Several geothermal provinces in India, see Figure 2, characterized by high heat flow (78-468 MW/m^2) and thermal gradients (47-100^{o}C/km) discharge about 400 thermal springs. After the oil crisis in the 1970s, the Geological Survey of India conducted reconnaissance survey on those, in collaboration with UN organization.

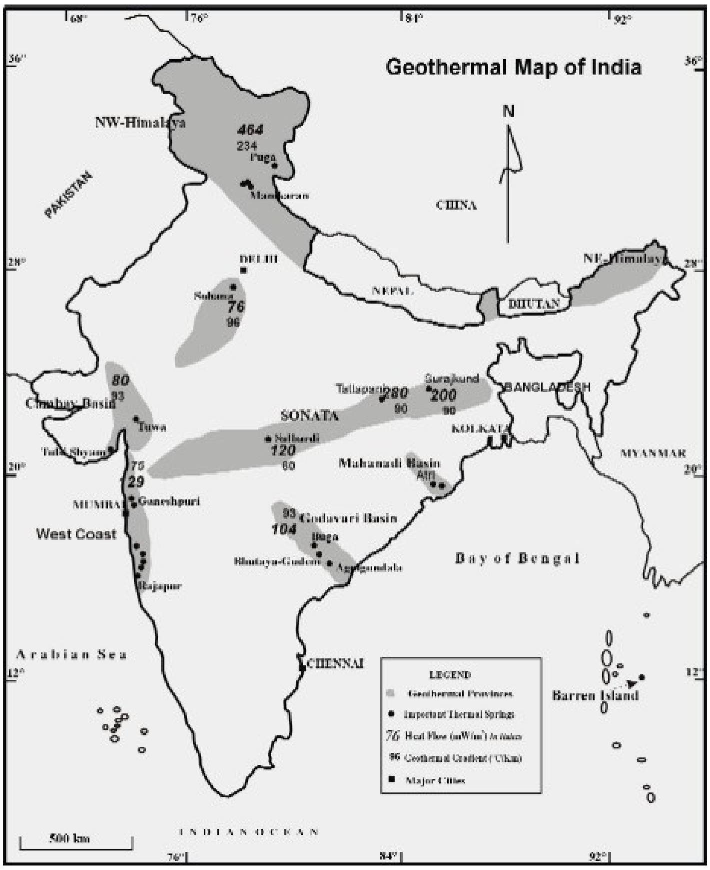

Figure 2: Map showing the geothermal provinces of India. Shaded regions represent geothermal provinces (Chandrasekharam, D., 2005)

India has a huge potential for geothermal energy, but has not yet taken the great step towards utilization. Nevertheless, they are just now starting the commercial process for realizing this. It is well known that India has used direct heat in a more simple way for a long time for heating, cooking and bathing. Other potential applications are different industrial processes and heating of greenhouses as for example is practiced in Iceland.

Figure 3: Geothermal manifestations in the north-western part of Himalaya (Chandrasekharam, D et. al., 2003)

Geologically, many of the springs are situated in the Himalayan Geothermal Belt, see Figure 4, where the Indian plate collides with the Tibetan plate and is being subducted. The collision and ongoing subduction process have created the fantastic Himalayan mountain range.

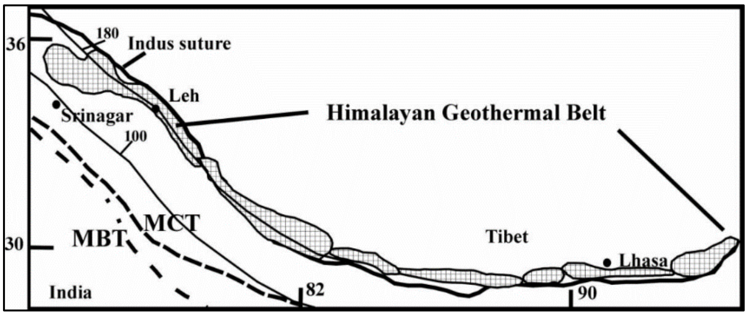

Figure 4: Map showing the geothermal provinces in the Himalayan region. Gray areas represent geothermal provinces (Chandrasekhar, V. and Chandrasekharam, 2007).

3. DEMONSTRATION SITE IN CHUMATHANG

3.1 Chumathang village

The Chumathang area is located approximately 138 km from Leh, on the way to Puga in the Ladakh Region of Jammu and Kashmir province in north-west India. This is a high altitude area located at around 4150 masl. It is a sparsely populated area, and Chumathang is a village that has a restaurant (Lamjing restaurant) with some rooms for rent and a small hotel (Hot Spring Resort) for travellers along the way to Tso Morari. The Tso Morari Lake is the largest of the high altitude (4595 masl) lakes in the Trans-Himalayan biogeographic region. Close to the village, a minor military camp is situated. As Chumathang is laying so high, it has a steppe climate, with very little rainfall. The annual precipitation is about 174 mm. The temperature goes down to -16 to -17°C in the winter and up to 19-20°C in the summer. The average annual temperature in Chumathang is around 2°C.

The area is also famous for being a geothermal hot spot. Hot water is bubbling up at springs along the Indus riverbed, which runs close to Chumathang village, on the south side of the main road. The small hotel Hot Spring Resort is warmed up by spring water during the winter. Most of the existing springs are located along the riverbed, but some are situated in and above the village.

3.2 Geology and available data

Geologically, the area around Chumathang comprises three distinct geological units (Figure 5). The northern unit consists of sedimentary rocks of shallow marine to fluvial facies and Cenomanian to Miocene age belonging to the Indus Group. The Chumathang Granite belonging to Ladakh granites, is exposed close to the site of the Chumathang geothermal field, intrudes the sedimentary sequences.

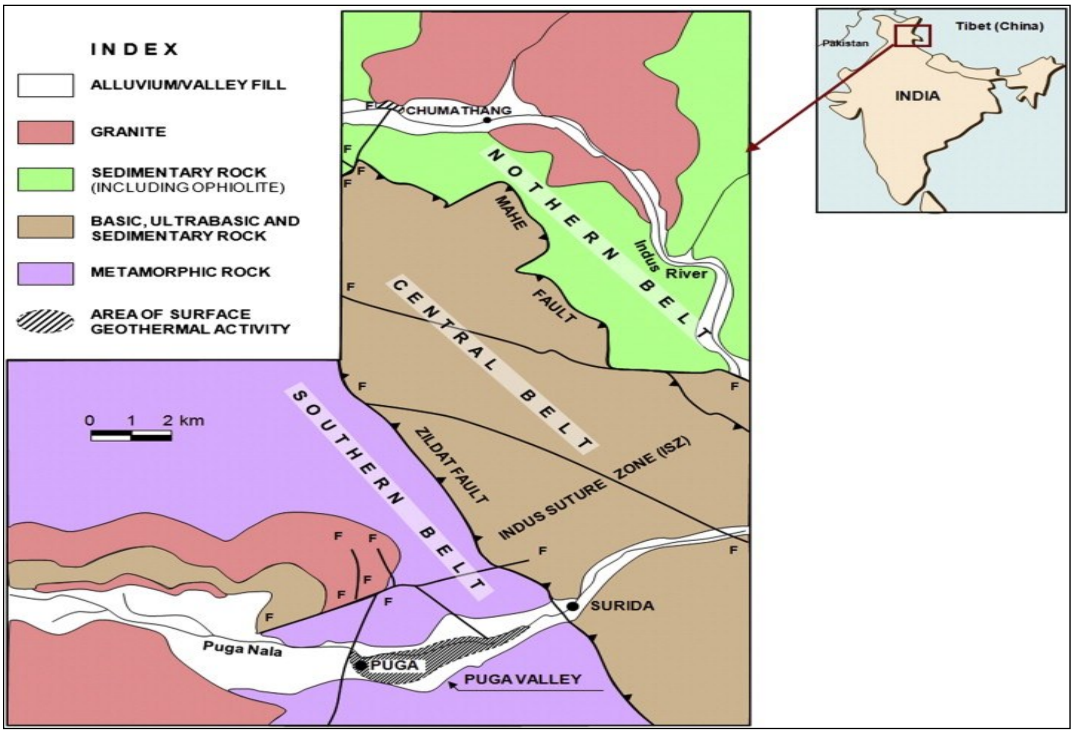

Figure 5: Geological map of Puga Valley and Chamuthang area, Ladakh showing the major tectonic structures. (In Craig et al 2013, modified from Shankar et al., 1991 and Azeez and Harinarayana, 2007

The central unit corresponds with the Indus Suture Zone itself and is characterized by a thick sequence of basic, ultrabasic rocks and associated sedimentary rocks (fossiliferous limestone) belonging to the Sumdo Group. It is bounded by the NE–SW trending Mahe Fault to the north and the sub-parallel Zildat Fault to the south. The southern belt consists of a thick succession of sediments, metasediments and metamorphic rocks intruded by granites (Harinarayana et al., 2006). The intensity of metamorphism increases broadly from northwest to southeast, such that the rocks exposed in the southern belt are typically highly deformed and of medium to high metamorphic grade. The Chumathang - Puga Valley lies within the southern tectonic belt and appears to be a down-faulted block bounded to the west by the NNE–SSW trending Kiagor Tso Fault and to the east by the major NW–SE trending Zildat Fault, with its northern and southern bounding faults concealed beneath recent valley fill.

Between 1973 and 1975, the National Geophysical Research Institute and other Indian National Agencies performed geophysical exploration. Attempts have been made to collect information of sub-surface disposition of the thermally anomalous area by undertaking vertical electrical soundings, magnetic survey, Self-Potential (SP) and gravity survey (by Geological Survey of India).

Geophysical studies indicate that the thickness of the unconsolidated valley fill in the area of the Chumathang geothermal field ranges from 15 to over 100 m from seismic refraction data. Magnetotelluric surveys indicate a low resistivity zone of 13–30 Ω/m up to a depth of 300 m. This has been interpreted to suggest that the geothermal activity is vigorous to this depth (Thussu, 2002), although it could also reflect the presence of clay-rich sediments or alteration. Chemical thermometry suggests a deep reservoir temperature of at least 145 °C. The Chumathang field is considered suitable for the installation of a 3 to 5 MWe Binary Power Plant (Craig et al 2013).

There is limited information on how many boreholes are in the area. But some new drilling was carried out in 2013. A total of six wells have been drilled to a depths of 20 to 221 m (Fig 6). The maximum temperature recorded in these wells is 110°C and the reservoir temperature at that time was estimated to be in excess of 130°C. In addition to these, the army has drilled a few wells on the upper side of the main road where one of them was very promising. This well produced a lot of steam that carried over the village, and had to be plugged.

The old shallow wells have indicated a very high temperature gradient ranging from 0.7 to 2.5 °C/m. Nevertheless, this project focuses on using the existing hot springs. As mentioned before, most of them are situated along the Indus riverbed, but there also is one close to the restaurant. This will be used for the pilot project.

Temperature measurement performed at some of the springs along Indus riverbed showed surface temperatures of about 87°C that is close to boiling temperature at the present latitude. However, the hot water temperature recorded at the hot spring outlet near restaurant was about 78˚C and at the pipe outlet was 63˚C. The ambient temperature measured during readings was -5˚C. Changes in ambient temperature may be reflected slightly in the temperatures at the hot spring and pipe outlet.

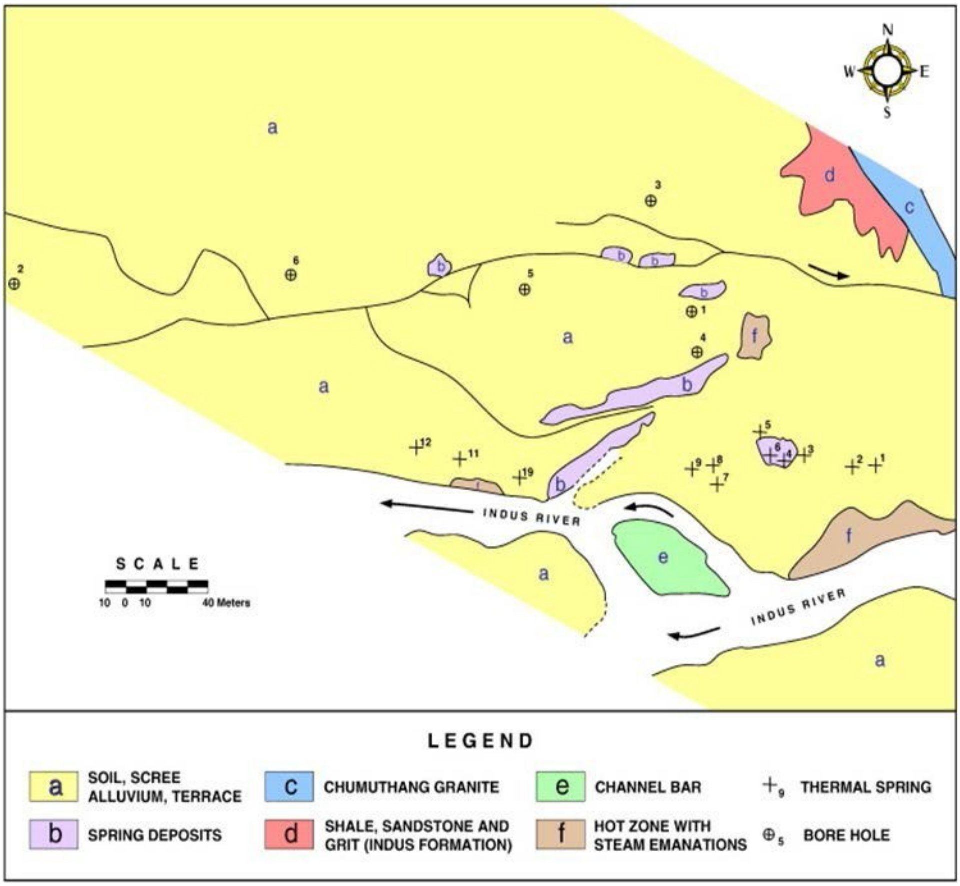

Figure. 6: Geological map of the Chamuthang geothermal system, Ladakh, Jammu & Kashmir State Modified from Waza et al., (1977) showing location of bore wells and thermal springs.

3.3 Space heating in Chumathang

The space-heating project in Chumathang is an Indo-Norwegian project with participants from Iceland, Norway and India. The main objective is to demonstrate how geothermal water can be used for space heating in the north-western Himalayas in India, based on existing technology in other geothermal countries as for example Iceland. A few of the main challenges in implementing the pilot project are summarized below:

- Chumathang is located in a rural area high up in the mountains where the houses are badly or not at all insulated,
- Electrical power is available only during 3 hours per day
- Potential risk of scaling and corrosion on the geothermal side of the heat exchanger needs to be considered
- A plumber with experience in this kind of heating installations is not available in the area

Space heating is among the most important direct uses of geothermal energy worldwide. This kind of application has a long history in Iceland where about 90% of all houses are heated by geothermal energy, partly from low-temperature areas and partly from combined heat and power plants (CHP) using steam from high-temperature areas. Most commonly, the heat is supplied to the users through a district heating system composed of a pipe network connecting the buildings to a supply centre or pumping station, but individual systems serving only one or a few buildings are also common. Two main types of heating systems exist. In a direct throughflow (open) system the geothermal fluid is pure enough and not too hot to allow its pumping directly from the borehole through the customers heating system, which commonly is composed of water radiators. The returning water is disposed of through the local wastewater system. In a heat exchanger (closed loop) system, the geothermal fluid is used to heat up water in a secondary loop that circulates through the heating installations in the buildings (radiators). This system is chosen if the geothermal fluid is unsuitable for using it directly due to its chemical composition and also if the geothermal fluid needs to be mixed with antifreeze fluid to prevent freezing of the water in a cold climate. Since temperatures well below zero can be expected in Chumathang during winter, a closed loop system with antifreeze fluid has been selected.

The pH value of the water in Chumathang field ranges from 6.9 to 8.6. The water has higher SO_4 concentration and low Cl, Na, HCO_3 and K. The fluid is classified as sodium bicarbonate and sulphate type. The base temperatures calculated using Na-K, Na-K-Ca and SiO_2 thermometry are found to be 145-166°C, 160-184°C and 148-174°C, respectively (Chauhan, 2013).

The main parameter influencing the heat demand of a building is the outdoor ambient temperature, although other factors like wind speed and solar radiation are also important. Figure 7 shows long-term average values for three characteristic outdoor temperature values in the Chumathang region, monthly average, minimum and maximum temperature. The figure shows that the outdoor maximum temperature reaches the room temperature required for human comfort, 20°C, only one month in a year. Temperatures below zero prevail in the area for more than six months a year, reflecting the requirement for space heating in the region (Chauan, 2013).

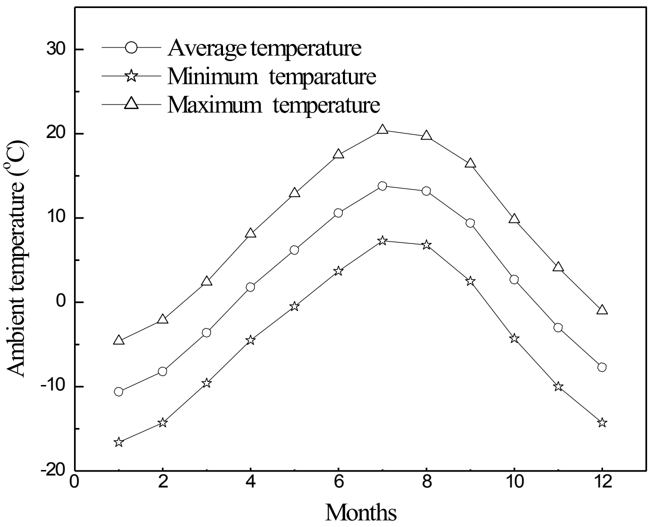

Figure 7: Monthly average outdoor temperature in Chumathang (Chauan, 2013)

The heating system in Chumathang is based on a hot spring located only about 15 m from two small buildings, a restaurant and a guesthouse (Fig 9). The elevation of the hot spring is about 4 m lower than the buildings. Water is flowing naturally from the hot spring at a temperature of 78 °C. This water is used mainly for washing clothes and is to some extend pumped to the restaurant and used as tap water. The natural flow of the water is used for washing (see Figure 8 right) and has been measured to be about 1 l/s although the total flow spread over an area surrounding the hot spring is considerably larger than that. The chemical analysis of the geothermal water indicates that it could be used directly in a throughflow heating system without risk of scaling or corrosion problems in the pipes or radiators. However, a heat exchanger system has been chosen as mentioned before. The reason is that, in periods during winter with low ambient temperature, a break in operation of the heating system, for example as a consequence of pump failure, could cause the water in the pipes located outdoors to freeze. To prevent freezing in the outdoor pipes, a closed loop is chosen with fresh water mixed with 30% antifreeze fluid (ethylene glycol) that circulates through the radiators. A direct throughflow would have been more attractive if the hot spring would have been located at a higher elevation than the building, which is not the case.

Figure 8: Left; hot spring that will be used for the Pilot project. Right; facilities for washing clothes.

Of the many types of heat exchangers available, the brazed plate type is the most widely used heat exchanger for residential systems. The main reasons are: (a) the plate heat exchanger requires less space in terms of m^3/kW than other types; (b) the high turbulence in plate exchangers, even at Reynold's numbers as low as 10 to 400, results in very effective heat transfer characteristics and inhibits fouling of heat transfer surfaces; (c) the brazed type is of a much lighter construction and easier to handle than other types. This type of heat exchanger will be installed as a part of the heating system in Chumathang.

The heat exchanger will be located close to the hot spring in a small shelter. The geothermal water is led from the hot spring through hot dip galvanized steel pipes and pumped through the heat exchanger by a 370 W self-priming electrical pump. The design conditions (during the coldest period of the year) are 75°C inlet temperature to the heat exchanger and 45°C at the outlet where the geothermal outlet water will be led to the run-off from the hot spring. The design conditions for the other side of the heat exchanger where the radiator water is circulated by a 200 W electrical pump through the closed loop are 70°C at the outlet and 40°C at the inlet. The flow rate on each side of the heat exchanger is at these conditions 0.18 l/s giving a heating capacity is 29 kWt.

The heat is supplied to the buildings through a total of eleven conventional wall mounted water radiators of steel type. Two of them are located in each of the three rooms in the guesthouse and the rest is located in the restaurant, mainly under the windows, as appropriate. The flow rate through the radiators is controlled by return water temperature sensors. The pipes in the network connecting the radiators with the heat exchanger are mainly steel pipes, 1" in diameter, except for the outdoor part that is about 20 m long and made of 32 mm pre-insulated plastic pipes (PEX).

The total floor area of the two buildings is about 75 m^2 and the heating system is designed for a capacity of 29 kWt. This is a few per cent in excess of the calculated heat demand at peak load. It should be noted that the heat demand in these building is much greater than in buildings in Scandinavia of similar size due to very limited insulation of the houses in Chumathang. In addition, the restaurant has a large facade with single glass windows, which makes the heat losses huge.

Among the challenges faced in the process of designing the heating system was the lack of stable availability of electric power to run the two electrical pumps. Since the hot spring is located at a few meters lower than the buildings, pumping of the water is necessary. In the present situation, electricity from the grid is only available for about 3 hours per day in the evening. Additional power can be generated by diesel generators, but this is not a viable option for continuous operation of the heating system. The solution chosen was to install solar panels on the roof of the guesthouse to supply electricity for the pumps. Six sets of panels will be connected in parallel, each of them consisting of four panels connected in series, i.e. totally 24 solar panels. They will charge four 12 volts batteries connected in series. The DC output will be inverted to AC to supply up to 2.000 W at 220-230 volts. An automatic bypass switch, integrated in the inverter switches, switches from the batteries to the electrical grid whenever it is available. This system should enable 24 hours operation of the pumps. The solar panel system was supplied and installed by Hima Industrial Corporation in early June 2014.

Figure 9: LamjIng restaurant with the spring to the left (close to the person in blue jacket).

The design of the heating system for the pilot project has been done by the consulting company VERKIS in Iceland. A schematic diagram of the system is shown in Figure 10, where the main components are the hot spring, heat exchanger, pumps, transmission pipes and radiators. Figure 11 shows the system layout for the electrical supply to the pumps in the heating system.

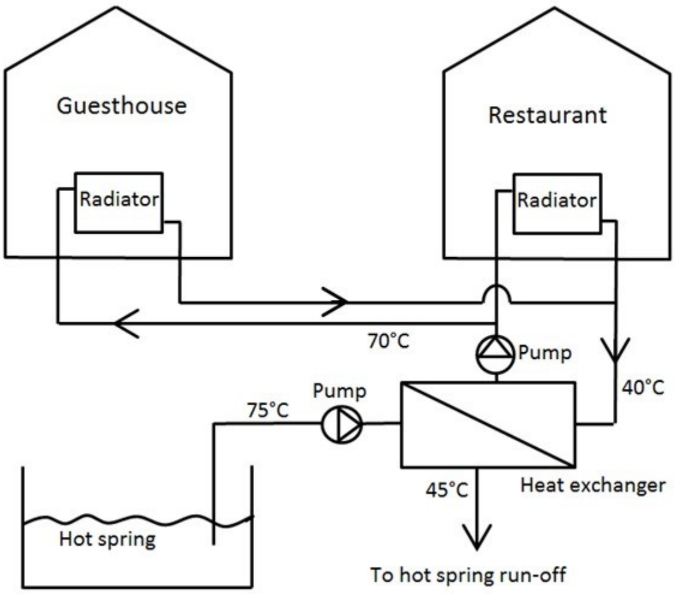

Figure 10: Schematic diagram of the space heating system in Chumathang.

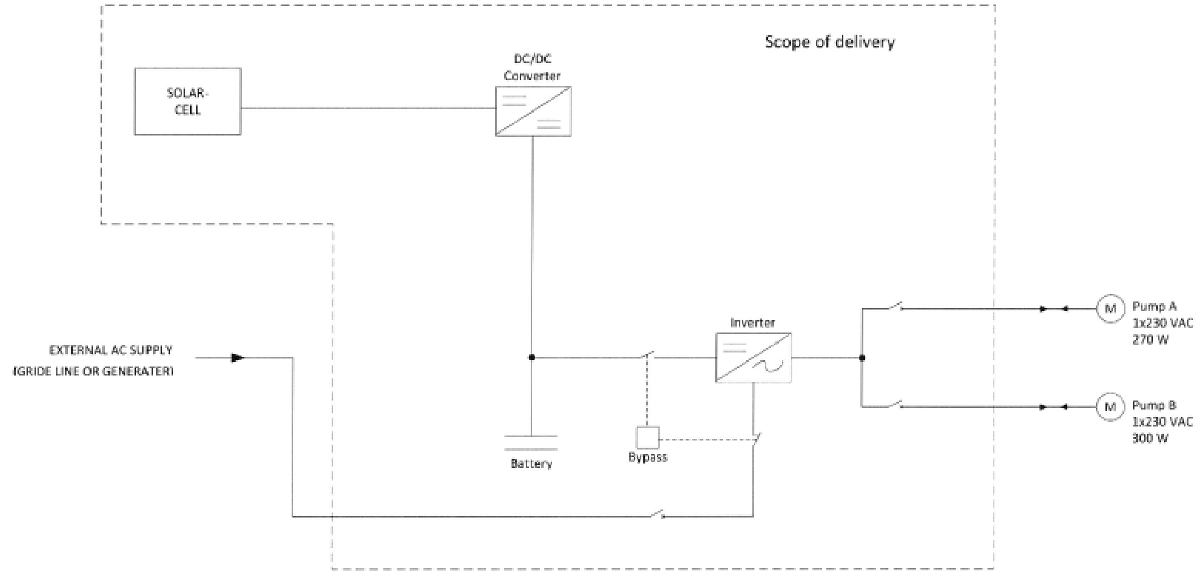

Figure 11: System layout for the electrical supply to the pumps in the heating system.

All of the piping material, radiators and other equipment needed for installation was shipped from Iceland in April 2014. According to the present plan, the plumbing work will start at the end of June and the system should be ready for testing in the beginning of July 2014. The installation of the heating system will be made by an Icelandic plumber with a long experience in this kind of work.

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