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Social Impacts of Geothermal Utilisation in Puga, Ladakh, India

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ABSTRACT

Access to energy is critical in development of any society in any corner of this planet. Puga is a rural area in Ladakh region of Jammu and Kashmir, India, situated 177 km away from Leh town. People are heavily dependent on fossil fuels like kerosene, wood for their heating requirements due to absence of reliable electricity grid. Women of the area have to do most of the household chores and it's the woman who suffers the most as they are not able to use any electrical appliances like washing machines, electric cook stoves etc. Most of their time is spent in collecting fuel and doing the daily chores manually. As a result they do not get opportunities to either earn or get education. Most of the people living in this area send their children to Nomadic Residential School (NRS).

The paper focuses on providing 24 hours electricity by installing a Binary power plant to the Nomadic Residential School (NRS) at Puga. With the existing geothermal well and surface temperature of 80°C it is possible to generate more than 60 kW of electricity which is more than enough to electrify the building for 24 hours. It also discusses the design of heating system for the Nomadic Residential School, Puga, using the available geothermal fluid. Calculation was made for heat load of the building without insulation (present scenario) and with building insulation. The results show that for long term energy saving it will be good to insulate the building which will reduce the heat load by more than half of the present heat load. This will be a clean energy solution providing comfortable indoor temperature of 20°C (even when outside temperature can go below -20°C).

The utilization of Puga geothermal field will provide access to clean and affordable energy (United Nations Sustainable Development Goal, UN-SDG 7) along with gender upliftment (UN-SDG 5).

1. INTRODUCTION

Estimated geothermal potential of India is 10,600 MWe from more than 300 sites with more than 20 hot springs in the state of Jammu and Kashmir (Craig et al., 2013). Chumathang and Puga in the Indus valley and Panamik in Nubra valley are said to have geothermal potential between 3 and 20 MW_e.

The scope of this report is to use the existing flowing geothermal well without further drilling in Puga to generate electricity which will be enough to electrify and run the direct heating system for the Nomadic Residential School, Puga. At present the boarding school is heated using wood or kerosene. For electricity there is a 10kVA standalone generator which supplies electricity to the boarding school from 6pm to 11pm. There are three villages nearby namely Sumdo TR, Sumdo and Korzok. Sumdo and Sumdo TR have no access to electricity at all. The electricity requirement of Korzok is fulfilled by a diesel generator of 82.5 kVA/66 kW which only operates from 6 to 11 pm (District Statistical and Evaluation Office, 2015). With the coming up of the new administration block in Puga there will be more demand for electricity which can be met up from this plant.

The utilisation of this source is important keeping in view the fact that the fuel required to electrify these areas must be transported from other states of India in tankers travelling 3000 km.

The exploitation of this field is very important at a stage when the whole world is fighting to combat CO2 emission and to fulfil India's goal in combating Climate change/ global warming along with achieving United Nations Sustainable Development Goal 7 which ensures access to affordable, reliable, sustainable and modern energy for all.

2. BACKGROUND

2.1 Field Information

Puga shown in Figure 1 is a valley located at 4550 metres above sea level with a latitude of 33˚13' N and longitude 78˚18' E at the junction of Indian and Tibetan plates along the Indus Suture Zone and has geothermal manifestations in the form of hot springs, mud pools, sulphur and borax deposits covering an area of 15 km^2.

Figure 1: Map showing geothermal field of India.

Puga geothermal field is bounded by faults and its reservoir rocks consist of granite, gneiss and schist. Geophysical surveys show a low resistivity zone below the Puga field. Methodical and comprehensive evaluation of the field begun in 1973. Out of the 34 wells that were drilled 17 wells had mixed steam and water blow-outs. Some wells show discharge of more than 120 °C. Thermal studies show temperatures of more than 220 °C at 2200 metres depth while Chemical thermometry shows a reservoir temperature of 250 °C and reservoir modelling shows temperature of up to 160 °C at 450 metre depth. The geothermal fluid has high concentration of lithium, rubidium and caesium indicating that the heat source for Puga is a magmatic source. Observations indicate that the Puga field could sustain a 20 MWe power plant.

A speciation calculation was made using the WATCH computer program for the geothermal water at 85°C, assuming pH = 8.2, suggests that the water is exactly at the saturation limit with respect to calcite at this temperature. Therefore, there should be no risk of calcite scaling when the water is cooled during utilisation due to the higher solubility of calcite with decreasing temperature (Pers. Comm., Finnbogi Óskarsson, Geochemist, ISOR, September 2017). On the other hand, some minor precipitation of amorphous silica may occur upon cooling as the silica concentration of the water is rather high (207 mg/L) according to Shanker et al. (2000). However, the silica concentrations reported by Craig et al. (2013) are rather lower (120-165 mg/L) and should not cause significant precipitation of amorphous silica.

2.2 Weather and Ambient Air Temperature

The minimum temperature in the region goes to -25 °C and maximum is 25°C (Pers. Comm. Dorjey Wangchuk, Engineer Incharge, Indian Institute of Astrophysics, Leh, August 2017). Figure 2 shows the maximum and minimum temperature for the period 2002 to 2011.

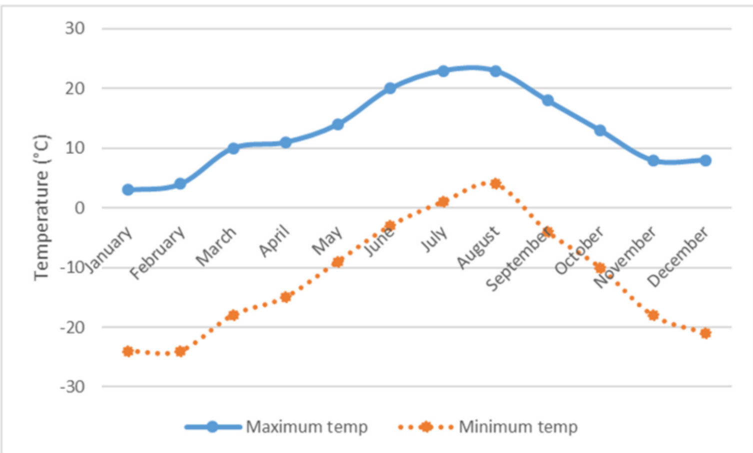

Figure 2: Temperature for Changthang.

3. POWER PLANT

There is no electricity grid available in Puga, except for the standalone diesel generator engine of 10 kVA. The diesel generator will most likely be used as a reserve in the future. The ORC power plant has thus to be able to start without any power present.

In case the pressure from the wells is not sufficient to get enough fluid running through the ORC heat exchangers to start the plant, a "tank" design must be used, where the low pressure natural flow is collected into a tank (Figure 3). The heat exchangers with the working fluid at the tube side are then dipped into the pool. The disadvantage of this design is that oxygen from air will be absorbed in the geothermal water and cause corrosion, unless appropriate corrosion resistant material is used for the heat exchangers. Since water is scarce in the area, air cooled condensers will be used to cool the working fluid coming out of the turbine.

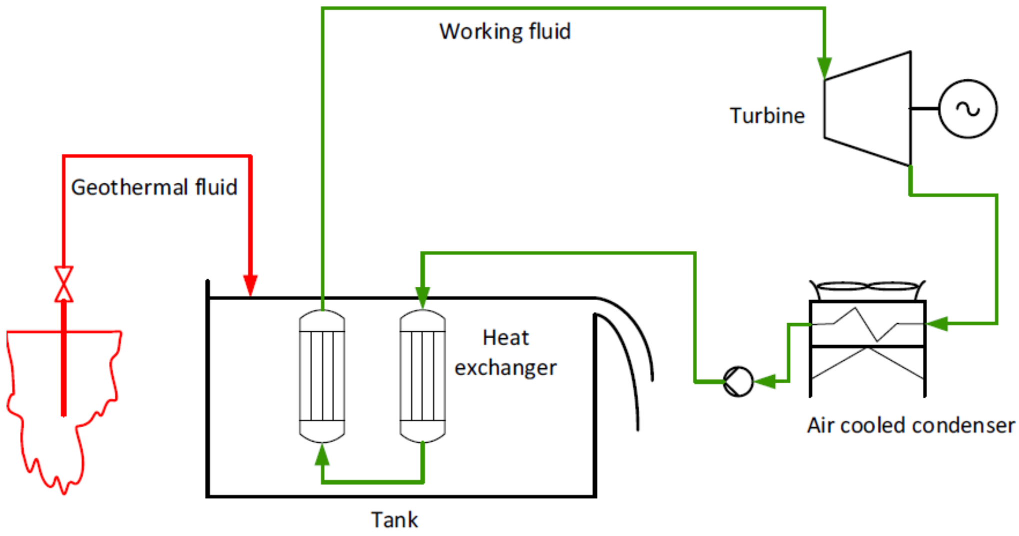

Figure 3: Schematic of power plant with "Tank".

3.1 ORC Plant Design

Here we have assumed a traditional shell and tube heat exchanger requiring geothermal fluid pressure of say 1.5 or 2 bar absolute at the inlet of the heat exchangers (Figure 4). The geothermal fluid is on the inside of the tubes, and the working fluid on the shell side. The inside of the tubes can be mechanically cleaned, if there is any dirt or precipitation present from the geothermal fluid. The shell can be manufactured from inexpensive black steel as the working fluid is not corrosive. The tubes will most likely have to be made out of corrosion-resistant steel as the geothermal fluid is very likely to be corrosive for black steel.

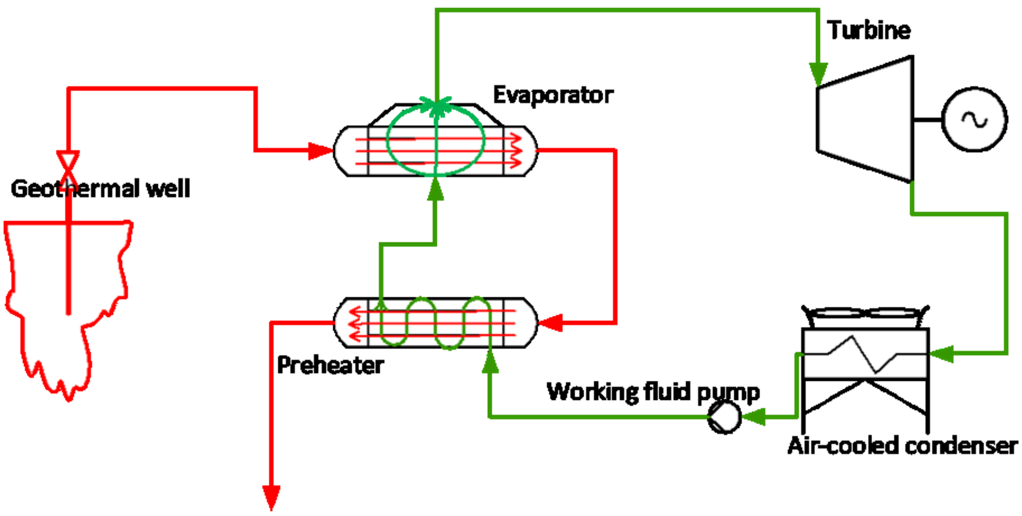

Figure 4: Diagram of the shell and tube heat exchanger plant.

The ORC working fluid is in a closed circuit in the plant. The fluid is condensed into liquid phase in the air-cooled condenser and enters the circulation pump as liquid at low temperature and low pressure.

The circulation pump increases the working fluid pressure up to the vaporizer pressure which has been selected for the plant. The liquid working fluid is now at high pressure and enters the preheater, where the fluid is heated by the geothermal fluid up to a temperature just below the boiling temperature at the selected working fluid pressure.

After that the working fluid enters the vaporizer, where the fluid is heated further to the bubble point, where boiling starts, and the first vapour bubble is created in the fluid.

The boiling of the working fluid continues then in the vaporizer at constant temperature, where higher and higher mass fraction of the working fluid has changed phase from liquid over to vapour. Heat for the vaporization process is taken from the geothermal fluid on the shell side of the vaporizer. Finally, there is no liquid present anymore, and all the working fluid has been transformed into vapour. The vapor becomes very slightly superheated by contact with the hot geothermal fluid tubes above the liquid surface in the vaporizer.

The high-pressure vapour enters now the turbine or screw expander, whichever has been selected. There the working fluid vapour expands down to the condenser pressure and performs work, which is transferred to the generator as shaft power. The spent vapour from the turbine is now at low pressure and is led to the air-cooled condenser, where it will condense into liquid.

3.2 Calculation Model

A calculation model was made in Engineering Equation Solver (EES) using thermodynamic equations. The model was run for different working fluids and was checked for the best power output using different working fluid like Propane, Isobutane, Isopentane, n-butane and R134a. Except Propane all the other working fluids showed similar results as shown in the nose diagram in Figure 5.

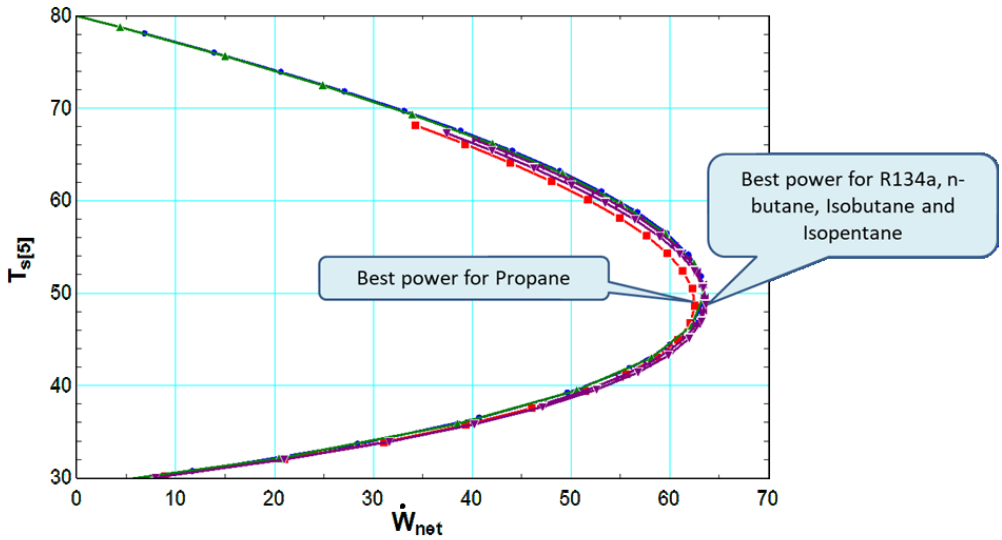

Figure 5: Return temperature vs net power output (KW).

The model shown in Figure 6 is based on R134a. R134a is the selected working fluid due to low price, and being no-toxic and non-flammable. Figure 6 shows the calculation model at the best evaporator pressure with thermodynamic stations and outputs. A condensation temperature of 35°C is assumed, which corresponds to roughly 10°C air temperature

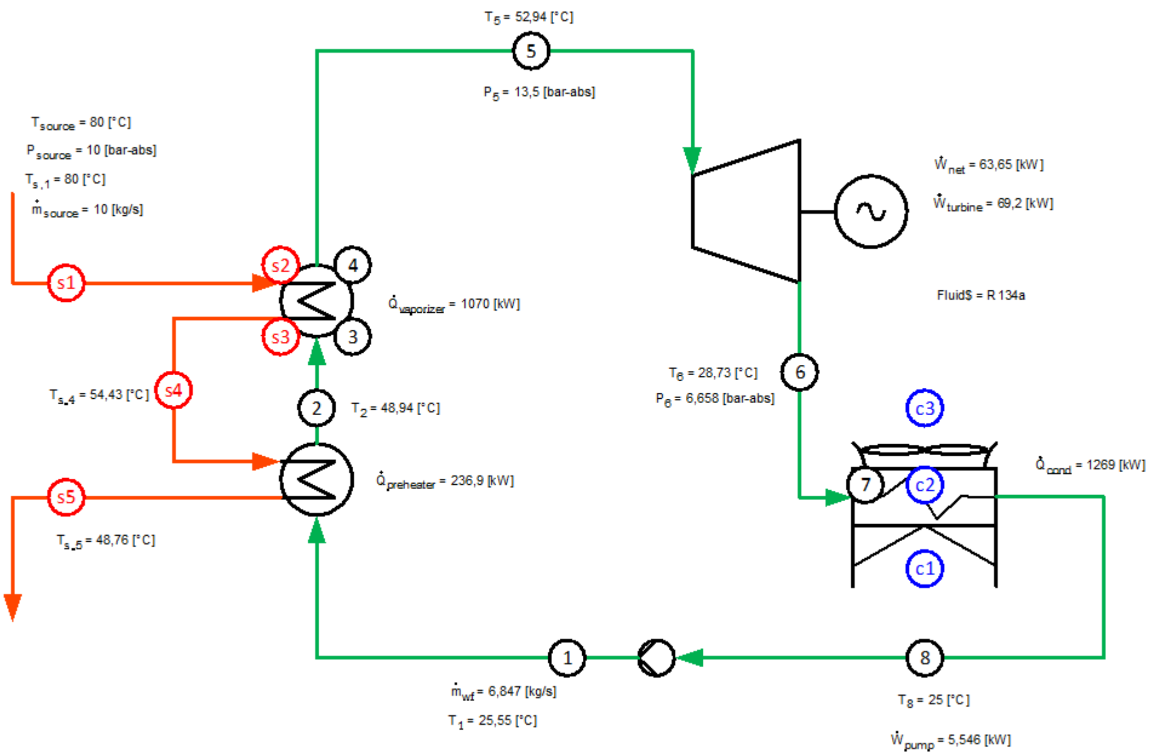

Figure 6: Calculation model of the binary power plant.

4. HEATING SYSTEM

The temperature in Puga ranges from -25 to 25°C as can be seen from the temperature plot from 2002 to 2011 in Figure 2. Heating is required for almost 7 months a year due to the extreme cold conditions.

4.1 The Building to Be Heated

Nomadic Residential School (NRS), Puga was started in the year 2004 by Ladakh Autonomous Hill Development Council (LAHDC), Leh, for the Nomadic children of several villages like Korzok, Koyul, Katley, Chumur, Mahey, Samad, Sumdo, Angkung and Kharnak etc. These are the nomads who rear the authentic Pashmina in the world. They must move from one place to another for the grazing of their cattle like Yak and Pashmina goat due to which their children face difficulty in having a stable education. NRS, Puga is now among the best government schools in Leh district.

The design condition of the school building to be heated is given in Table 1.

Table 1: NRS, Puga building design condition.

Building design conditions	
Latitude	33°13´ N
Elevation	4550 masl
Indoor temperature	20°C
Outdoor temperature	-25°C
Name of building	Puga Nomadic Residential School
Distance from the hot spring	1.6 km
Building Insulation	Nil

4.2 The Proposed Heating System

The proposed heating system will heat the building using the geothermal fluid which can heat the building for 24 hours. The building calculations are based on the building plans shown in Figure 7 and Figure 8.

Figure 7: First floor plan of Nomadic Residential School, Puga.

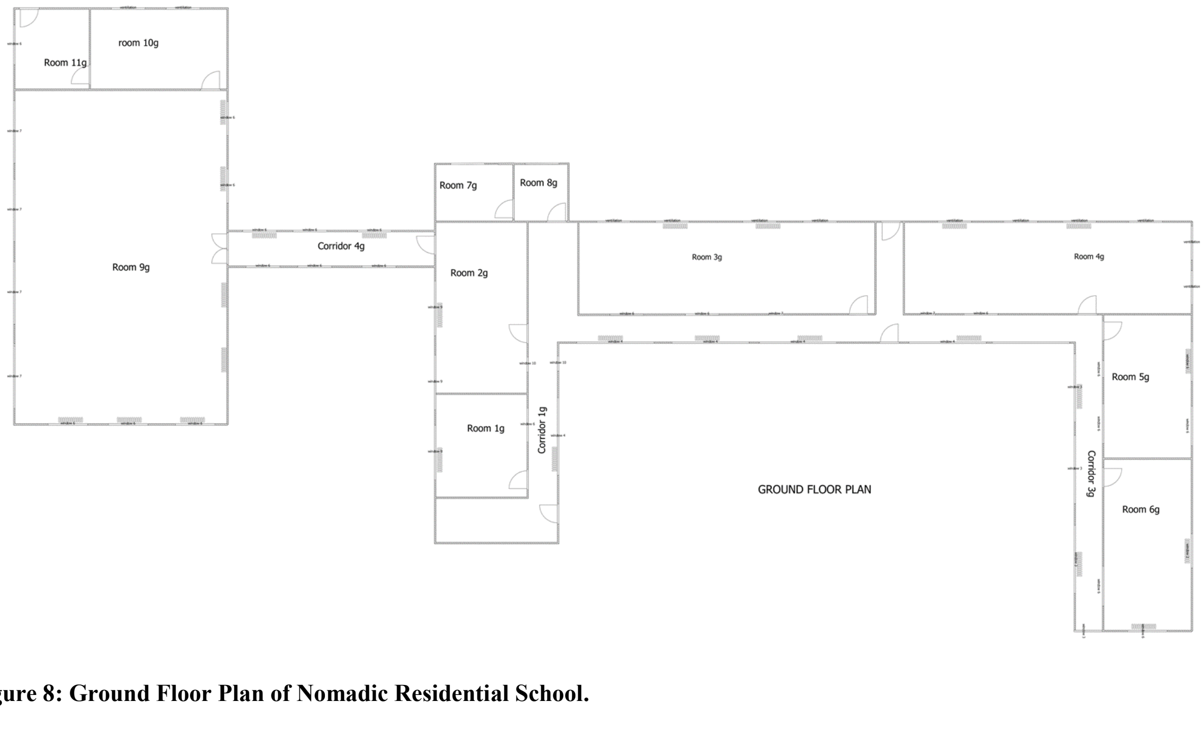

Figure 8: Ground Floor Plan of Nomadic Residential School.

4.3 Heat Load Calculation

The purpose of a building's heating, ventilating and air-conditioning system (HVAC) is to maintain a comfort and well-being of the occupants. The procedure followed in the head load calculation is (Idntaeknistofnun Íslands, 1984):

- Selection of constant indoor design temperature of 20°C
- Selection of outdoor design temperature -20°C
- Calculation/selection of the overall heat transfer coefficient, U, for walls, roof, windows, 1 m outer floor, inner floor and doors with the consideration that there is a 15% heat loss due to radiation through the roof
- Calculation of the heat load due to transmission and infiltration

The detailed design and heat load calculation is beyond the scope of this report.

4.4 Benefits of Improved Building Insulation

The building has no insulation at present. It is suggested that for energy efficiency, the building should be insulated. These conditions can be considered in the future to reduce the heating requirement of the building. The potential savings (Dickson and Fanelli, 2003) can also be seen in Table 2.

Table 2: Effect of insulation on building heating demand.

Insulation criteria	Typical heating demand (kWh/year)	Glazing type
Insignificant insulation	>100000	Single
Poor insulation	55300	Single
Icelandic building code	30000	Double
Swedish building code	26800	Triple
Super insulation	22500	Quadruple

5. PROPOSAL

Deep drilling of more than 2000 m will provide geothermal fluid with temperature of above 200°C. As a beginning binary power plant of 20 MW capacities can be set up in this field which can act as a base load for Leh district which can run 24/7 unlike the hydroelectric power plants which run under capacity especially in winters. The geothermal potential of the region need to be utilised in order to have a sustainable source of energy rather than using fossil fuels.

6. CONCLUSION

The available geothermal source in Puga can be utilised to provide 24 hours electricity and heating the boarding school for the students. The utilisation will make the building sustainable in that it will not have to depend on fossil fuels which are used at present to electrify and heat the building. These fossil fuels are now transported from the main town of Leh which is 176 kms away. At present the building has no insulation at all due to which there is a huge heat load. For long term benefit and energy saving the building should be insulated which will reduce the heating load by more than half of the present.

The implementation of this project will bring a change in the lives of the students living here. They will have 24 hour electricity which will be a dream come true. They will not have to bother about wood and kerosene for heating and keeping them warm in the cold winter months. They will be able to enjoy living in a clean environment with this sustainable energy solution. They deserve this much luxury as they prepare for their future living at such high altitude.

This will be one of the steps towards fulfilling the United Nations Sustainable Development Goals.

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