Total Run-of-River type Hydropower Potential of Nepal

Raghunath Jha

Abstract: The total hydropower potential of Nepal was assessed as 83,500 MW in 1966 by Dr. Hari Man Shrestha during his PhD research work in former USSR. Since then, no further study has been done in this field. The hydropower potential estimate has been used by Nepal Electricity Authority (NEA), Water and Energy Commission Secretariat (WECS) and Department of Electricity Development (DOED) for power development, licensing and policy making. However, keeping in view recent advancements in computer technology that offer many benefits to the field of water resources and the importance of power estimation in Nepal, Dr. Shrestha's estimate needs further review and updating. The present study has mainly used the hydro-meteorological data of Department of Hydrology and Meteorology (DHM) for hydrological analysis of all the rivers in Nepal including the three big rivers, viz., Saptakoshi, Narayani and Karnali, and other medium and small rivers. Incorporating GIS and the Hydropower Model that has specifically been developed by the author, the power potential and annual energy estimate on an run-of-the-river (ROR) basis of the entire country has been worked out. The result shows that the power potential and annual energy estimates of Narayani, Saptakoshi and Karnali River basins at Q40% (flow exceedence) and 80% efficiency are 17800, 17008, 15661 MW and 113373, 108817, 102324 GWh, respectively. The Mahakali River would yield only 2262 MW of hydropower and 14981 GWh of energy annually. The other water sources in Nepal would have a total power potential of 1105 MW and a combined annual energy of 7043 GWh. Thus, the total hydropower potential and corresponding annual energy capacity of Nepal on a ROR basis at Q40%, and 80% efficiency is 53,836 MW and 346538 GWh, respectively.

Key words: Hydropower potential, Run-of- River (ROR), GIS, Hydropower Model, Nepal

Background

The total hydropower potential of Nepal was assessed as 83,500 MW in 1966 by Dr. Hari Man Shrestha during his PhD research work in former USSR. Since then, no further study has been done in this field. Dr. Shrestha's work was accomplished with the limited tools available during that time. Also, the hydrological, meteorological and topographical data available during that time were insufficient and of poor quality, especially for Nepal.

According to Dr. Shrestha, only four gauging stations were available in Nepal. The precipitation data available were, however, a little more than the discharge data. His work curves were plotted between rainfall and elevation bands. From the analysis of those curves, discharges were calculated using the regression equation developed by using the limited discharge data available from the four discharge measuring stations and the rain gauge stations.

Similarly, manual delineation of a catchment area of about 300 sq km was done with old topographical maps. The available heads along the rivers were calculated using contour intervals and the discharge was calculated by means of contour interval and elevation-rainfall curves. According to him, each drop of water was used to calculate the power potential and the considered efficiency was 100%.

The 1966 power potential estimate has been used by Nepal Electricity Authority (NEA), Water and Energy Commission Secretariat (WECS) and Department of Electricity Development (DOED) for power development, licensing and policy making. Under the policy of the government with priority to small, medium and large hydroelectric/power and multipurpose projects at different points in time, these organizations have assessed power potential of individual projects. It has been realized that the past effort of identifying undeveloped hydropower capacity by the different government agencies is more project-oriented, and the methodology for undeveloped hydropower resources assessment is not well defined. It is also important to note that apart from Dr. Shrestha's assessment, no agency has attempted to estimate the undeveloped hydropower capacity of Nepal on a river basin approach using the site characteristics, stream flow data and available hydrologic head. In a country of huge hydropower potential like Nepal, this issue has to be properly addressed and the methodology has to be developed.

Recent advancements in computer technology have offered many benefits in the field of water resources. The Geographic Information Systems (GIS) is such a tool with diverse applications. GIS in conjunction with the Hydropower Model could be used in a variety of hydrologic applications like delineating the drainage pattern, catchment area and assessing hydropower potential of the river reaches.

With all these understandings, this study has thus been carried out with the objective of calculating the theoretical hydropower potential of the entire country of

Nepal by using ArcGIS and Hydropower Model.

Methodology

The present study could be divided into the following three components:

a. Hydrological Analysis
b. GIS Analysis
c. Hydropower Model

Figure 1 shows the flow chart of the methodology of the research. Here, hydrological analysis leads to the basin and sub-basin wise discharge calculations. GIS analysis is aimed at calculating the elevation differences between various points of river reaches, flow accumulation, etc. Finally, the outcomes of these two are fed to the Hydropower Model, which calculates the power potential and energy.

Hydrological Analysis

Monthly discharge data of more than 100 river gauging stations from the year 1997 to 2006 were collected from the Department of Hydrology and Meteorology (DHM). Using these data, flow duration curves of each station were developed and the Q40, Q50, Q60 discharges were calculated for all the 12 months of a year. Here Q40, Q50 and Q60 represent the flow magnitude in an average year that could be expected to be equaled or exceeded 40, 50 and 60 percentile of the time respectively. The specific discharge, i.e., discharge divided by the catchment area contributing to the discharge at each gauging stations, were also worked out. It was then used to calculate the discharges at various points along the river reaches upstream and downstream of the gauging stations.

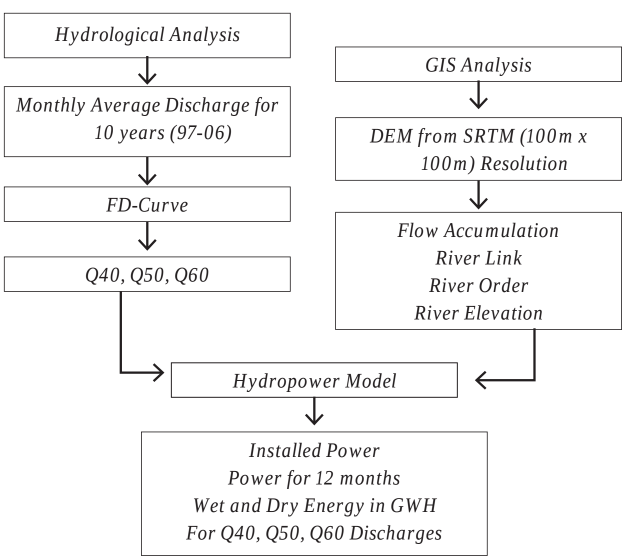

Figure 1. Flow Chart of Methodology

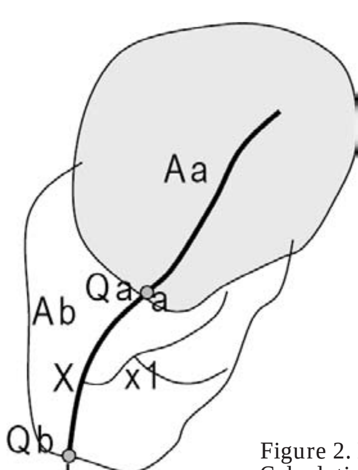

Figure 2. Discharge Calculation

As an example see Figure 2, where the catchment area and discharge at gauging stations 'a' and 'b' are Aa, Qa and Ab, Qb, respectively. The discharge up to gauging station 'a' could be calculated using the specific discharge at gauging station 'a'. The specific discharge at 'b' is calculated as (Qb –Qa)/ (Ab – Aa). The discharge along the main river at X, Qx is calculated as

$$Qx = Qa + (Qb- Qa)/(Ab-Aa) * (Ax-Aa)$$

where, Ax is the catchment area at x. The discharge at x1, Qx1 is calculated as

$$Qx1 = (Qb- Qa)/ (Ab-Aa) * Ax1$$

GIS Analysis

The freely available SRTM (Shuttle Radar Topographic Mission) dataset of 3" second resolution and WGS84 datum was downloaded from seamless SRTM datasets site (http://srtm.csi.cgiar.org/). The SRTM Decimal Degree format dataset was transformed to MUTM (Modified Universal Transverse Mercator) and Everest datum and resampled to 100m resolution. The available DEM was processed using GIS software and flow direction, flow accumulation, river network, stream order, stream link and elevation along the generated rivers were calculated. GIS Grid output of flow accumulation, stream order, stream link and river elevation were converted into the ASCII format and fed to the Hydropower model.

Hydropower Model

The Hydropower model used in the study work has been developed by the author and is written in the FORTRAN program language. This model reads the ASCII data processed in GIS software and calculates head from the river elevation. It reads discharge data processed in the hydrological analysis and calculates the installed capacity, wet energy and dry energy in all generated rivers and for all discharge percentiles. The flow chart of the model is given in the Figure 3.

A team of researchers, including Mr. Rupesh Sah (Rupesh 2009) and Sudip Prakash Adhikari (Sudip 2009) led by the author at the Institute of Engineering, Pulchowk Campus, Nepal, used the above software and calculated the hydropower for whole Nepal.

Study Area

Most of the surface water in Nepal drains through the four major rivers; i.e., the Saptakoshi, Narayani, Karnali

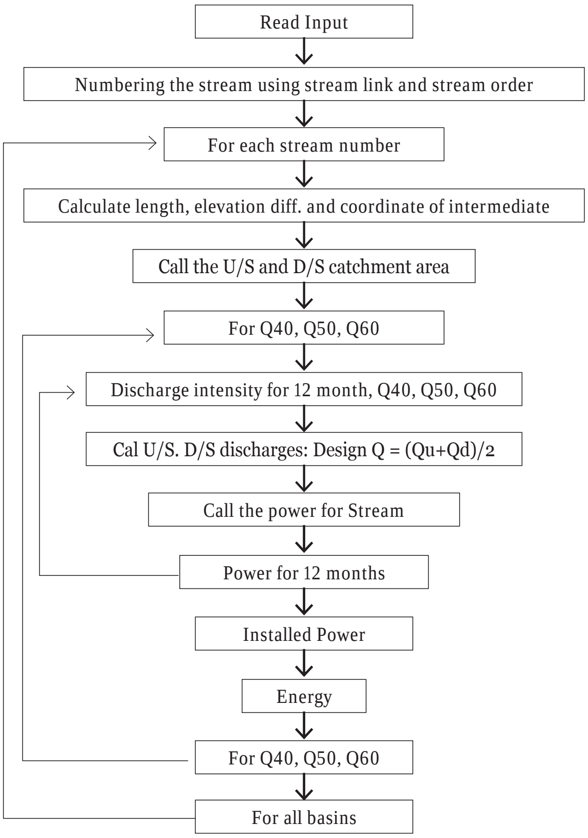

Figure 3: Flow Chart of Hydropower Model

and Mahakali and their tributaries. All of these originate either from the Himalayas or from the Tibet Plateau and are perennial.

Other major rivers such as Mechi, Kankai, Kamala, Bagmati, Tinau, Rapti, Babai, etc., originate from the Mahabharata ranges. The Mahakali and Mechi Rivers mark the international boundaries between Nepal and India.

Saptakoshi River Basin

The Saptakoshi basin is the largest river basin of Nepal. (See Figure 5.) It lies in the Eastern Development Region of Nepal. It encompasses a catchment area of 61,000 sq. km., of which 27,816 sq. km (i.e., 45.6%) lies in Nepal and the rest in Tibet. The highest altitude within the basin is at 8848m and represents the peak of the world; i.e., Mount Everest. The Saptakoshi River constitutes seven major tributaries; i.e., Indrawati, Sunkoshi, Tamakoshi, Likhu, Dudhkoshi, Arun and Tamor, from west to east. Out of these, three major rivers or tributaries originate in Tibet; the Sunkoshi, Tamakoshi and Arun.

Within the Saptakoshi basin, there are altogether 34 discharge gauging stations in different rivers: Majhimtar and Mulghat on the Tamor River; Uwagaon and Tudkeghat on the Arun River; Rabuwaghat on the Dudhkoshi; Sangutar on the Likhu; Rasnalu on the Khimti; Busti on the Tamakoshi; Pachawarghat on the Sunkoshi; Jalbire on the Balpeni, and Chatra on the Saptakoshi.

Narayani River Basin

The Narayani basin is the second largest river basin of Nepal. It lies in the western development region covering a catchment area of 31,890 sq. km.

The basin incorporates the districts of Manang, Nawalparasi, Baglung, Chitwan, Makawanpur, Mustang, Parbat, Palpa, Gorkha, Lumjung, Myagdi, Gulmi, Syangja, Dhading, Rasuwa, Kaski, Arghakhanchi, Tanahu, and Nuwakot. It ranges from the higher Himalayas to the Terai. The highest elevation in this basin is 7163m at Ganesh Himal and the lowest is 73m at the Indo-Nepal Border.

Karnali River Basin

The Kamali River is the third largest river of Nepal. It originates from the south of Mansarovar and Rakas lakes in China (Tibet) and enters Nepal near Khojarnath flowing in southern direction.

The drainage area of Karnali River in China is approximately 2500 km^2 and that in Nepal is approximately 41500 km^2. The total drainage area of the river is approximately 44000 km^2.

Mahakali River Basin

The catchment area of Mahakali River is approximately 15,260 km^2, out of which about 5400 km^2 (35%) are located in Nepal. The river has its origin in Api Himal within the Himalayas. It serves, for most of its length, as the western border between Nepal and India. The river starts from Milan glacier of India and from the Lipulekh

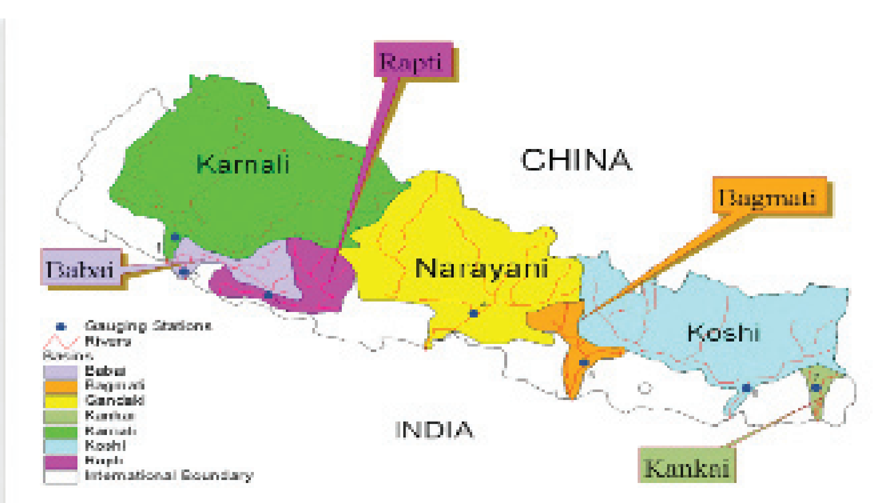

Figure 4. River basins in Nepal

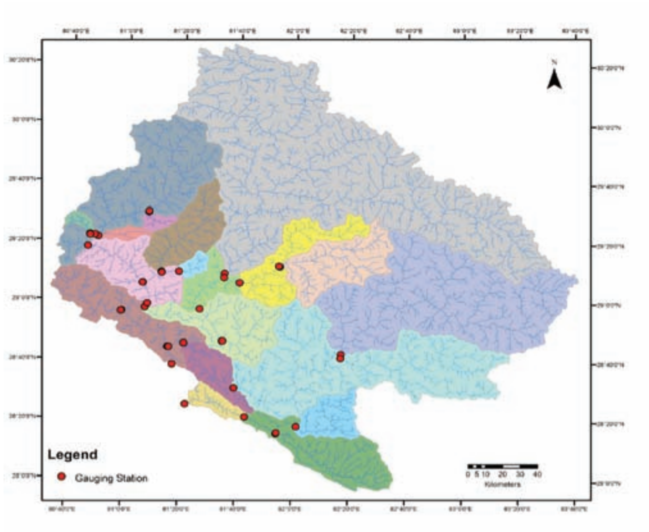

Figure 7. Karnali River Basin

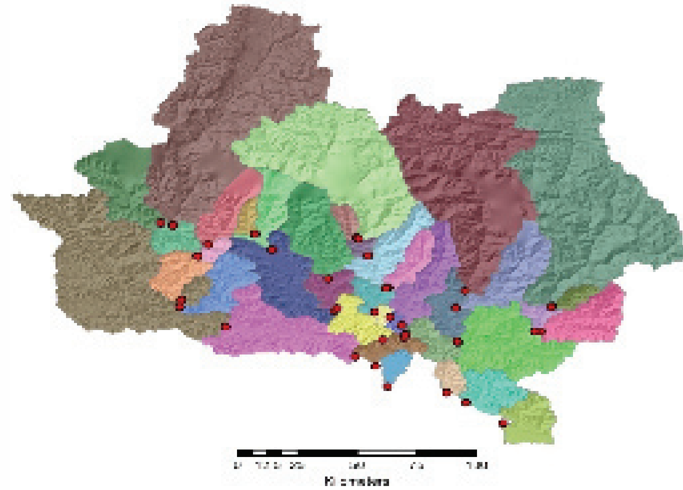

Figure 6. Narayani River Basin

Figure 5. Saptakoshi River Basin

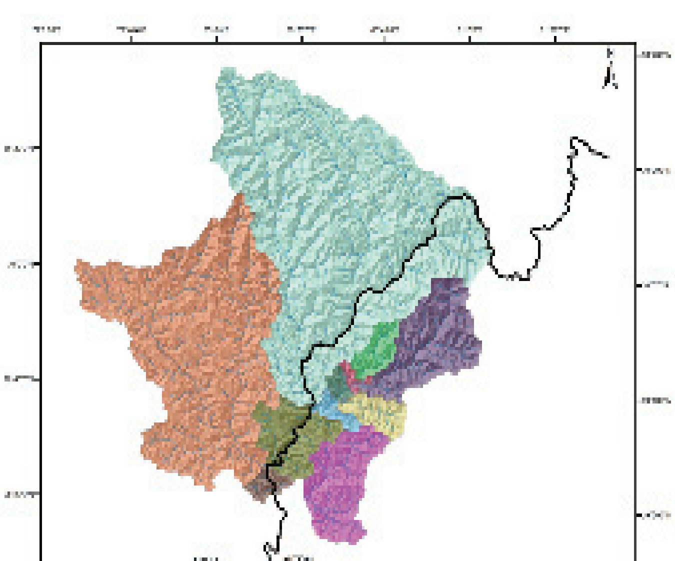

Figure 8. Mahakali River Basin

of Nepal and after flowing for a length of 223 km as a border river and making numerous oxbow lakes it finally enters India from the southwest corner of Nepal. Its main tributaries in Nepal side are the Surnagad River and the Chamelia River.

Results

The outcome of the study work using the Hydropower Model is presented on Table 6.1 below. It includes power potential and energy estimates of the Saptakoshi, Narayani, Karnali, Mahakali and other rivers. The following Tables 6.1, 6.2, 6.3 and 6.4 give the hydropower potential and annual energy estimates of the Saptakoshi, Narayani, Karnali and Mahakali Rivers, including their major tributaries at 40% flow exceedence and 80% efficiency.

It is observed that the power potential and annual energy estimates of the Narayani, Saptakoshi and Karnali River basins are 17800.2, 17008.3, 15661.16 MW and 113373.3, 108816.9, 102324.03 GWh, respectively. The Mahakali River would yield only 2261.83 MW of hydropower and 14980.9 GWh of energy annually. The other water sources in Nepal would have a total power potential of 1105 MW and a combined annual energy of 7043 GWh. Thus, the study shows that the total hydropower potential and corresponding annual energy capacity of Nepal on run-of river basis at 40% flow exceedence and 80% efficiency is 53,836 MW and 346538 GWh, respectively. This study also concludes that 50%, flow exceedence and 80% efficiency, total hydropower

Basin	Power Potential (MW)	Dry Energy (GWH)	Wet Energy (GWH)	Total Energy (GWH)
Tamor Basin	3643.5	2950.3	19694.1	22644.4
Arun Basin	4965.1	5780.2	27178.8	32959.0
Dudhkoshi	2741.5	2533.0	14872.2	17405.1
Likhu	607.5	537.8	3288.9	3826.7
Tamakoshi	2087.9	1611.1	11194.4	12805.4
Sunkoshi	2548.4	2593.9	13830.8	16424.7
Indrawati	414.4	481.9	2269.6	2751.5
Saptakoshi (Total)	**17008.3**	**16488.2**	**92328.6**	**108816.9**

Table 6.1: Power and Energy Estimates of Saptakoshi Basin at Q40

Basin	Power Potential (MW)	Dry Energy (GWh)	Wet Energy (GWh)	Total Energy (GWh)
Kaligandaki	4338.8	4027.3	23658.5	27685.8
Seti	780.0	698.3	4258.9	4957.1
Madi	477.5	460.4	2613.5	3073.9
Marsyangdi	3251.8	2823.5	17681.7	20505.2
Budhi Gandaki	3286.0	2747.2	17797.0	20544.2
Trisuli	5569.8	5365.0	30559.6	35924.6
East Rapti	96.3	139.0	543.6	682.5
Narayani (Total)	**17800.2**	**16260.7**	**97112.8**	**113373.3**

Table 6.2: Power and Energy Estimates of Narayani Basin at Q40

Basin	Power Potential (MW)	Dry Energy (GWh)	Wet Energy (GWh)	Total Energy (GWh)
Seti River	2060.08	2421.04	11346.98	13768.02
Karnali River	8328.48	8008.29	45378.28	53386.57
Budhi ganaga River	402.79	545.76	2213.50	2759.26
Bheri River	4140.75	4678.97	22683.37	27362.34
Babai River	106.60	143.98	585.26	729.24
Tila River(Sinjha Khola)	622.46	859.87	3458.74	4318.61
Karnali (Total)	**15661.16**	**16657.90**	**85666.13**	**102324.03**

Table 6.3: Power and Energy Estimates of Karnali basin at Q40

Basin	Power Potential (MW)	Dry Energy (GWh)	Wet Energy (GWh)	Total Energy (GWh)
Chamelia River	601.78	890.27	3351.75	4242.02
Surnagad River	16.84	25.39	93.04	118.43
Mahakali River	1643.21	1635.29	8985.16	10620.45
Mahakali (Total)	**2261.83**	**2550.94**	**12429.96**	**14980.90**

Table 6.4: Power and Energy Estimates of Mahakali Basin at Q40

potential and corresponding annual energy capacity of Nepal on run-of-river basis is 36,247 MW and 256,256 GWh, respectively. Similarly, 60%, flow exceedence and 80% efficiency, total hydropower potential and corresponding annual energy capacity of Nepal on run-of-river basis is 27,544 MW and 211,561 GWh, respectively.

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Reference

Sah, Rupesh, 2009, *Energy Mapping Using GIS & Hydropower Model in Koshi, Narayani, Bagmati and Kankai Basins*, unpublished MSc Thesis, Institute of Engineering, Department of Civil Engineering, MSc Program in Water Resources Engineering, Pulchowk Campus, TU, Lalitpur, Nepal.

Adhikari, Sudip P., 2009, *Energy Mapping Using GIS & Hydropower Model in Karnali, Mahakali and West Rapti Basins*, unpublished Msc Thesis, Institute of Engineering, Department of Civil Engineering, MSc Program in Water Resources Engineering. Pulchowk Campus, TU, Lalitpur, Nepal.

CALENDAR HYDROPOWER

27-30 July 2010: Hydro Vision International 2010, Location: Charolotte, North Carolina, USA
http://www.hydroevent.com/index.html

15 Aug. 2010: Accelerated Development of Hydro Power in Bhutan, Central Board of Irrigation & Power, India, http://www.cbip.org/upcomingeventsitelist.aspx

16-20 Aug. 2010, Hydropower Africa 2010 Location: Johannesburg, South Africa, More info: Email: dania.petrik@spintelligent.com, Website: http://saaea.blogspot.com/2010/04/hydropower-africa-2010.html

27-29 Sept. 2010, Hydro 2010, Location: Lisbon, Portugal More info: http://www.hydro2010.com/

28-30 Sept. 2010, 2nd International Congress on Dam Maintenance and Rehabilitation Location: Zaragoza, Spain More info: Email: sepremzaragoza2010@tilesa.es, Website: http://www.damrehabilitationcongress2010.com

13-14 Oct. 2010, British Hydropower Association Annual Conference 2010 Location: United Kingdom More info: http://www.british-hydro.org/forthcoming_events/bha_events/

30 Aug. – 3 September 2010, Contractual and Legal Framework in Hydropower Development, Organiser: International Centre for Hydropower, Location: Trondheim, Norway. More Info: www.ich.no/DynamicCourses.asp; e mail: mail@ich.no

21-24 Sep. 2010, Training on Procurement and Negotiations for Hydro Projects, Roorke, India, More info: http://ahec.org.in/

27 Sept. – 2 Oct. 2010: Small Hydro Resources, Organiser: International Centre for Hydropower, Location: Trondheim, Norway. More Info: www.ich.no/DynamicCourses.asp

25-29 Oct. 2010: Risk Management in Hydropower Development, Organiser: International Centre for Hydropower, Location: Trondheim, Norway. More Info: www.ich.no/DynamicCourses.asp

24-26 Nov. 2010:16th International Conference on Hydropower Plants, Location: Vienna, Austria More info: www.viennahydro.com/

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MinErgy Pvt. Wins "Best Innovative Clean Energy Program" Programme

Clean Energy Program" in the competition. There were in total 11 finalists at the competition, selected out of many applicants from all over the globe. Mr. Suyesh Prajapati, energy and environmental expert presented and received the award on behalf of MinErgy Pvt. Ltd.

Last year as well MinErgy won the award for "Best Innovative Clean Energy Technology" in Clean Energy Marketplace competition in 2009 for its project concept designed by Mr. Prajapati on "Application of renewable biomass solid fuel generated from forest waste as an alternative to the coal for firing bricks in Vertical Shaft Brick Kilns". Winning award at the Clean Energy Marketplace for two consecutive years is a big achievement for MinErgy Pvt. Ltd., a relatively new company run by a bunch of young people with innovative ideas and a passion for their work.

MinErgy Pvt. Ltd. is a Service Company based in Nepal and network member of Clean Air Network Nepal. It is formed as an offspring of a clean building technology project. MinErgy inherits the competency, skills, know-how and expertise of the Vertical Shaft Brick Kiln (VSBK) Project Nepal, which is being implemented by Skat, Switzerland with financial support of Swiss Agency for Development and Cooperation (SDC) since 2003.

It is indeed a great Achievement to receive two consecutive awards in 2 years in a row.