PAPER NO. 218

ROLE OF LOW HEAD POTENTIAL TO MEET THE ENERGY CRISIS IN PAKISTAN

BY

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BY

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1 INTRODUCTION

Pakistan is facing the problem of shortage of energy since its inception. The lack of sufficient and reliable power supply is becoming an obstacle in the way of economic growth and development. Due to local economical conditions, scare fossil fuel, limited gas resources and high prices of imported oil, big scale thermals have to be restricted. Nuclear power has problems and constraints of its own.

The country is fortunate to endow with great hydropower potential. Hydropower is a natural source of renewable energy. It is necessary to exploit it to its maximum extent being the cheapest sources of energy. Most of the exploitable identified hydro potential lies in the North of the country, where demand is limited. The major demand lies in Punjab and Sind Provinces. The high head and major hydels are economical in general, however, it should be realized that these have long gestation period, far from load centers, need huge overall investment, less attractive to private investors and have financing risks.

Therefore it is imperative to look for short gestation projects, close to load center, keep the overall cost minimum and attractive to private sponsors and lenders. Low head hydropower potential of the existing barrages and canal falls in the irrigation system may offer such solution. Electrical energy generated by low head plants may be expensive in general as compared to high head plants; however, the low head plants less than 20 MW may provide low tariff, if their connection with grid (at different voltage level) is considered.

This paper will deal with the past, present and future of low head hydropower development in Pakistan.

2 WHAT DOES LOW HEAD HYDEL MEANS?

Internationally hydropower plants are being classified due to technological aspects, water economy, energy economy, topography and head. However, classification on the basis of topography and head is the logical base especially from the point of view of the designer and the construction engineer. Therefore, the following three classification on the basis of topography/head are very common.

- Lowland Plants - Low Head Plants
- Hilly Area Plants - Medium Head Plants
- Mountainous Region Plants - High Head Plants

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Low head potential in Pakistan means, the potential available at barrages and canal falls in the plains of Punjab, Sind, NWFP and Balochistan **(Fig: 1)**.

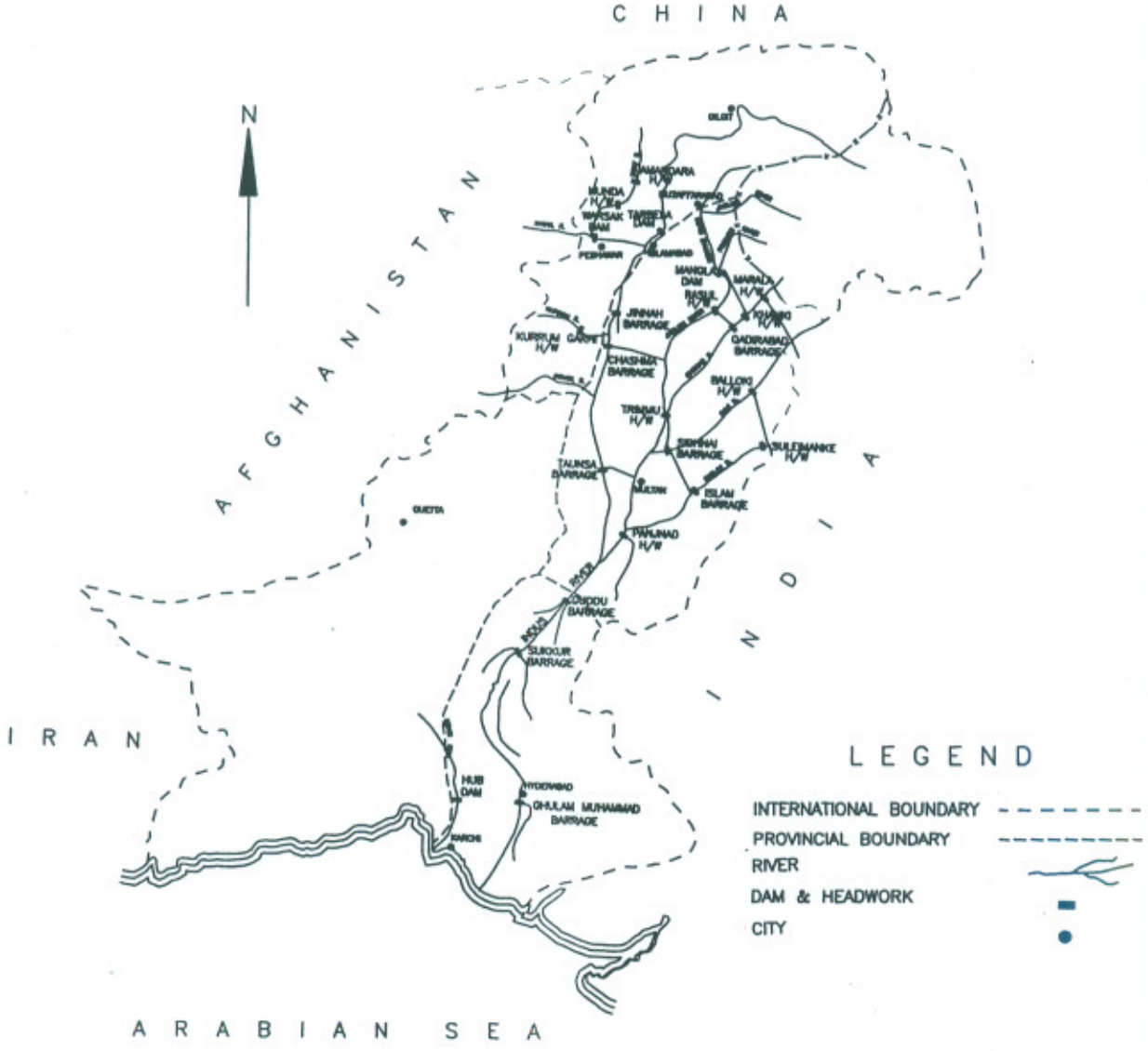


Figure 1: Map of Pakistan Showing Location of Dams, Barrages and Headworks.

Pakistan's river system is dominated by the Indus River. The principal tributaries of Indus within Pakistan are Shyok, Shigar, Gigit, Kabul, Swat, Kurram and Gomal on the right side and Siran, Haro, Soan, Jhelum, Chenab, Ravi, Beas and Satluj on the left side. The Indus river originates in the high mountains of Tibet and flows westward through Kashmir and Pakistan for almost 1600 km, where it turns and flows to the south out of the mountains and across the Indus plains about 1500 km, emptying into the Arabian Sea. The principal eastern tributaries join the Indus River after it enters the Indus plain. The Indus Plain is divided in to Upper Indus Plain with elevation more than 122 m.a.s.l (Punjab Province) and Lower Indus Plain with elevation less than 122 m.a.s.l (Sind Province). The Indus plain is being used for irrigated agriculture. The plain of NWFP is being irrigated by Swat River irrigation system.

The economy of Pakistan is entirely agricultural. About 75 % of the country population live in Indus plain in the Province of Punjab and Sind. However, to cultivate land successfully, irrigation is required.

Pakistan rightly claims to own the largest irrigation system in the world. The annual volume of water of the entire system is about 210 km3 (35 MAF), out of which about half is being supplied by the Indus. The whole irrigation system comprised of about **8 dams, 15 barrages, 6 Headwork (Table: 1)** and 72 canals. Most of the barrages and canals exist in the Provinces of Punjab and Sind. Pakistan irrigation system can be divided into:

- Indus Basin Irrigation System.
- Balochistan River Irrigation System.

Indus Basin is one of the largest single integrated irrigation system, is fed by river Indus and its left and right tributaries. With the inception of Pakistan, India announced her attention of using all water flows from India to Pakistan and closed the canals. The dispute was solved and an agreement" Indus Water Treaty 1960" was signed between Pakistan and India. As a result of this treaty, the rivers mainly Indus, Jhelum and Chenab were reserved for Pakistan and Ravi, Setluj and Bease were transferred to India. To overcome the effect of transferred rivers, dams, barrages and link canals were constructed. Through link canals and barrages a part of flows of Indus, Jhelum and Chenab River was diverted to river transferred to India to meet their irrigation requirement. Indus system can be divided into three systems namely:

- Indus River Irrigation System
- Left Tributaries Irrigation System
- Right Tributaries Irrigation System

Irrigation system consists of barrages/headwork and canals were constructed for water diversion and conveyance. Canals were provided with fall structures for bed stabilization and water diversion. During construction of irrigation system the development of hydropower potential along barrages and canals could not be taken up due to financial constraints. Only few power stations were constructed.

Table 1: Dams/Barrages/Headwork in Pakistan

Sr. No.	Name Of Structure	River	Location
	DAMS		
1.	Tarbela Dam ***	Indus	NWFP
2.	Khanpur Dam	Haro	NWFP
3.	Rawal Dam *	Korang	Punjab
4.	Mangla Dam***	Jhelum	Punjab
5.	Warsak Dam***	Kabul	NWFP
6.	Tanda Dam *	Kohat Toi	NWFP
7.	Baran Dam *	Baran	NWFP
8.	Hum Dam *	Hub	Balochistan
	BARRAGES		
1.	Jinnah Barrage**	Indus	Punjab
2.	Chashma Barrage**	Indus	Punjab
3.	Taunsa Barrage**	Indus	Punjab
4.	Guddu Barrage**	Indus	Sind
5.	Sukkur Barrage	Indus	Sind
6.	Kotri Barrage	Indus	Sind
7.	Rasul Barrage	Jhelum	Punjab
8.	Marala Barrage	Chenab	Punjab
9.	Qadirabad Barrage	Chenab	Punjab
10.	Trimmu Barrage	Chenab	Punjab
11.	Panjnad Barrage	Chenab	Punjab
12.	Balloki Barrage	Ravi	Punjab
13.	Sidynai Barrage	Ravi	Punjab
14.	Sulemanki Barrage	Setluj	Punjab
15.	Islam Barrage	Setluj	Punjab
	HEADWORK		
1.	Khanki	Chenab	Punjab
2.	Amandara *	Swat	NWFP
3.	Munda *	Swat	NWFP
4.	Bara *	Bara	NWFP
5.	Tanda *	Kohat Toi	NWFP
6.	Kurram Garhi *	Kurram	NWFP

Note.

* = Complete data of these projects was not made available.

** = These projects were studied during 1980s.

***= These are major hydel projects in the country.

3. LOW HEAD HYDROPOWER DEVELOPMENT IN PAKISTAN

3.1 Existing Low Head Station

Low head hydropower development is the pioneer and the oldest one, in generating electrical energy than other types such as thermal, medium and high head hydels in Pakistan. It actually started in the Punjab Province in 1925, by utilizing a fall of 3 m on Lower Bari Doab Canal off-taking from Balloki Headwork on Ravi River. This project is known by the name of Renala Hydel Station. In 1938 Malakand-1, a medium head plant was constructed in the North-West Frontier Province (NWFP) with a capacity of 7 MW on Swat River. Later, it was upgraded to 20 MW. In 1954, another hydel power station named Dargai having a capacity of 20 MW was constructed on the same canal. Then there was a series of hydropower plants constructed in the coming years. The important data regarding existing low head station is given in **Table: 2.**

Table 2: Data of Low (Small) Hydel Stations in Pakistan

Sr. No.	Name	Location		Power (MW)	Year of Construction	Remarks
		Canal	Province			
1.	Renala Hydel Station	Lower Bari Doab canal off-taking bfrom balloki Barrage	Punjab	1.1	1925	First Hydel Station
2.	Rasul Hydel Station	Upper Jhelum canal off-taking from Mangla Dam	Punjab	22	1951	
3.	Kurram Garhi-1,2 Hydel Station	Katchkot Feeder off-taking from Kurran Garhi Headworks	NWFP	4	1957	
4.	Chichoki Malian Hydel Station	Upper Chenab canal off-taking from Marala Barrage	Punjab	13	1959	
5.	Shadiwal Hydel Station	Upper Jhelum canal off-taking from Mangla Dam	Punjab	14	1961	
6.	Nandipur Hydel Station	Upper Chenab canal off-taking from Marala Barrage	Punjab	13.6	1965	
7.	Chashma Hydel Project	Indus River	Punjab	184	1999	Under construction

Thereafter, the development of low head hydropower projects within the irrigation system was ceased due to unknown reasons, whilst the development of large dams started in 1962 (Warsak Dam). Soon after, construction of Mangla and Tarbela Dam projects was started.

Recently after a very long break, the construction of Chashma hydropower project has been started at Chashma Barrage.

Data regarding installed capacity, plant factor and cost of generation of all hydel stations in Pakistan is presented in the **Table-3.**

Table 3: Data of Hydel Stations of Pakistan

Sr. No.	Project Name	Power (MW)	Plant Factor (%) (1975-95)	Average Cost of Generation (Ps/kWh) (1975-95)
1.	Tarbela	3478	52.68	5.61
2.	Mangla	1000	68.52	2.43
3.	Warsak	240	35.30	9.59
4.	Dargai	20	64.98	3.75
5.	Malakand-I	20	66.57	2.22
6.	Rasul	22	32.98	9.43
7.	Shahdiwal	14	42.92	10.53
8.	Nandipur	14	45.10	13.40
9.	Chichoki Mallian	13	37.16	10.00
10.	Kurrum Garhi	4	71.17	11.87
11.	Renala	1	60.92	34.40

3.2 Planned/Identified Potential

In early 1980s, when Kalabagh dam was under planning, it was realized that large hydel projects have long gestation periods and take quite sometime for implementation. At the same time, development of other inventoried projects was expensive due to remoteness of the site. Therefore, ranking study "Low Head Hydro Power at Barrages and Canal Falls" of the ten (10) selected sites **(Table: 4)** along exiting barrages and canal falls were taken up and completed in 1984 by WAPDA-HEPO in collaboration with German Agency for Technical Cooperation (GTZ).

Table 4: Selected Sites for First Ranking Study

Sr. No.	Location
1.	Jinnah Barrage on Indus River
2.	Chashma Barrage on Indus River
3.	Taunsa Barrage on Indus River
4.	Guddu Barrage on Indus River
5.	Khanki Headwork on Chenab River
6.	Chashma-Jhelum Link Canal Tail
7.	Balloki-Sulemanki Link I Canal RD 106+000
8.	Balloki-Sulemanki Link I Canal Tail
9.	Rohri Canal RD 15+000
10.	Rohri Canal RD 118+000

The site of Khanki Headwork was not studied in view of remodeling plans by the Punjab Irrigation department. The objective of the ranking study was to establish, an overall raking on the basis of the basic characteristics and feasible reconnaissance level layouts.

The advantages of these locations are;

(i) Closer to the load centers.
(ii) Short gestation period.
(iii) Availability of infrastructure.

Thus resulting in substantial saving in the overall cost of the project.

To ameliorate the energy situation, a number of projects **(Table: 5)** have been studied up to feasibility level in Public and private sectors.

Table 5: Data of Planned Projects.

Sr.No.	Name	Location	No. of Units	Power (MW)	Energy (GWh)	Remarks
1.	Jinnah HPP	Right Side of Jinnah Barrage	8	96	688	Final Feasibility is ready and project has been allotted to Marubeni of Japan in private sector for its implementation.
2.	Taunsa HPP	Right Side of Taunsa Barrage	8	120	624	Feasibility study under preparation and project allotted to Independent Energy Partners of America in private sector for its implementation.
3.	Guddu HPP	Left Side of Guddu Barrage	5	33.5	198	Model Studies in progress
4.	Rohri HPP	Rohri Canal RD 15+000	4	16	102	Project approved and allotted to French Consortium for Implementation on Turn Key Bases in Public sector
5.	C.J.Link HPP	Right Side of Fall Structure	2	22.5	347	Feasibility under Final Review. The project allotted to Independent Energy Partners of America in private sector for its development.
6.	B.S.Link I RD 106	Right Side of Fall Structure	3	10	68	Feasibility prepared in private sector by M.K.Power.
7.	B.S.Link I Tail	Right Side of Fall Structure	2	10	72	Feasibility prepared in private sector by Shaukat Hydel
8.	D.G.Khan Link-III	Left Side of Fall Structure	2	7.2	30.25	Draft Feasibility is prepared by HEPO-WAPDA.
9	New Bong Escape	Right side of Bong Canal	4	45	300	Feasibility report prepared BY Harza for private sponsor M/S Laraib.

3.3 Inventoried Potential

In early 1990s, a comprehensive inventory of the available hydel potential at existing canal falls and barrages along the irrigation system was undertaken. This was considered a complementary work to the ranking study of the pre-selected sites and comprised almost all barrages and main canals and their tributaries. The tributaries having discharge less than 30 m3/s in some places did not considered, due to non-availability of data.

3.3.1 Barrages /Dams

Thirteen locations out of 22 **(Table:** 1) were studied in detail. The remaining can not be studied due to limited available data. The water and discharge data was collected for the

years 1979-1987. The data of earlier years was not considered reliable, due to erratic operation of Tarbela. The data of the remaining location is still to be needed.

The dams/barrages were classified according to the seasonal variability and availability of stream flows. The estimation of energy and power potential was made according to different ranges of discharge, an upper range from 100 to 600 m3/s and a lower range from 10 to 150 m3/s were established. However, Khanpur dam was analyzed for 4 and 8 m3/s. Five (5) sites out of 13 have capacity less than 5 MW **(Table: 6)**. The total installed capacity ranges from 35 MW to 175 MW.

Table 6: Hydropower Potential of Dams/Barrages/Headwork

RIVER	BARRAGE	HEAD (m)		DESIGN DISCHARGE		POWER (MW)	ENERGY (GWh)
		Max	Min	m^3/s	av.% of Time		
INDUS	SUKKUR	3.5	0.5	100 600	85 50	2.91 15.41	15.01 59.71
	KOTRI	7.4	2.4	100 600	40 28	5.94 29.32	17.58 70.35
JHELUM	RASUL	7.0	4.1	100 600	45 20	4.98 23.12	16.76 61.08
CHENAB	MARALA	4.6	2.5	100 600	65 35	3.80 18.88	17.84 68.71
	KHANKI	2.3	0.5	100 600	50 25	2.17 8.47	6.00 18.65
	QADIRABAD	5.6	1.5	100 600	50 25	3.76 17.70	13.05 47.97
	TRIMMU	5.1	1.9	100 600	65 30	4.03 18.38	21.48 64.42
	PANJNAD	5.2	1.6	100 600	55 25	4.17 19.49	16.10 51.50
RAVI	BALLOKI	4.0	1.8	10 150	75 25	0.35 4.10	2.08 13.07
	SIDHNAI	5.2	1.6	10 150	55 20	0.42 4.65	1.70 11.80
SUTLEJ	SULEMANKI	2.7	1.0	10 150	60 15	0.41 4.68	2.40 11.17
	ISLAM	6.5	3.3	10 150	45 10	0.55 6.69	2.41 12.54
HARO	KHANPUR DAM	39.56	19.45	4 8	75 5	1.30 2.59	9.43 18.86

3.3.2 Canal Falls

Longitudinal sections of the canals and other drawings of the respective fall structures were collected from the field offices of the concerned Provincial Irrigation Departments. The collected data in the form of design, existing and proposed water levels and discharges tabulated. Seasonal variations in flows like Rabi and Karif have also been recorded. The full supply discharge and difference of full supply water levels were used for power potential calculation. The falls with site limitation such as siphon, transition, etc. did not considered even with reasonable head.

The inventory of canal falls (perennial and non-perennial canals) comprises a total of 586 sites. The head available at these falls varies between 0.03 to 13.83 m. Most of them have head less or equal to 1.0 m. The power potential at each canal falls was evaluated. Gross power potential available is about 550 MW.

Energy estimation was not done due to non-availability of historic flow pattern. Optimization studies were also not carried, which may allow higher output. Cost per unit of energy generated was not established due to non-availability of site data.

In order to select some suitable sites from a long list, a selection criteria was used which comprises;

- Only perennial canals were considered.
- Minimum head of 2.5 m (Only 45 falls have head more than or equal to 2.5 m).
- Selection of sites as per regulation in Pakistan (WAPDA is responsible for sites having capacity of 5 MW and above where as projects less than 5 MW fall under the jurisdiction of Provincial Governments).

Further, individual falls **(Table 7)** and combination **(Table 8)** of 2 or more falls were studied to have capacity of 5 MW and above. For combination of falls maximum distance of 100 RD was taken as limit. A total of about 180 MW could be exploited. Development of sites less than 5 MW capacity was studied on individual falls and about 40 MW potential can be available. However, the combination of falls may increase the number of sites for less than 5 MW.

Table 7. Hydro Potential of Individual Canal Falls Development More Than 5 MW

No.	Province	River	Barrage/Dam	Canal	R:D. (1000 ft.)	Head (m)	Discharge (m^3/s)	Power (MW)
1	PUNJAB	CHENAB	MARALA	Upper Chenab Canal	0+000	2.69	477.14	10.5218
2	PUNJAB	CHENAB	PANJNAD	Panjnad Canal	0+000	2.84	270.91	6.3090
3	PUNJAB	INDUS	CHASHMA	Chashma Jhelum Link	0+000	2.75	614.48	13.8565
4	SIND	INDUS	KOTRI	Kalri Baghar Feeder Lower	0+000	5.01	194.11	7.9744
5	SIND	INDUS	SUKKUR	Nara Canal	25+000	2.31	566.32	13.0233

Potential = 51.688 MW

Table 8. Hydro Potential of Combined Canal Falls Development More Than 5 MW

Sr. No.	Province	River	Barrage/Dam	Canal	No. of Falls	Development Stretch Length (km)	Head (m)	Discharge (m^3/s)	Power (MW)
1.	NWFP	SWAT	AMANDARA	Machai Branch Canal	7	12.73	19.18	48.73	7.6730
2.	NWFP	SWAT	AMANDARA	Machai Branch Canal	6	18.00	19.09	40.66	6.3640
3.	NWFP	SWAT	AMANDARA	Machai Branch Canal	6	16.78	17.70	40.66	5.9010
4.	PUNJAB	CHENAB	KHANKI	Lower Chenab Canal	2	12.25	3.53	230.58	6.6740
5.	PUNJAB	CHENAB	MARALA	Upper Chenab Canal Lower	2	11.09	5.02	266.69	10.9780
6.	PUNJAB	CHENAB	MARALA	Upper Chenab Canal Lower	2	5.21	3.02	230.64	5.7110
7.	PUNJAB	JHELUM	MANGLA	Upper Jhelum Canal	3	2.85	3.54	275.81	8.7006
8.	PUNJAB	RAVI	BALLOKI	Lower Bari Doab Canal	3	18.98	6.49	182.25	9.6980
9.	PUNJAB	RAVI	BALLOKI	Lower Bari Doab Canal	3	21.45	8.28	195.95	13.3040
10.	PUNJAB	SUTLEJ	SULEMANKI	Pakpattan Canal	2	3.84	4.50	160.16	5.3200
11.	SIND	INDUS	SUKKUR	Nara Canal	2	7.62	3.91	566.34	18.1570
12.	SIND	INDUS	SUKKUR	Nara Canal	2	18.29	5.06	542.75	22.5190
13.	SIND	INDUS	SUKKUR	Rohri Canal	2	8.00	3.87	248.79	7.8950

Potential = 128.8946 MW

4. DOES LOW HEAD POTENTIAL OFFER BENEFITS?

In early 1980s, the low head projects were taken up due to the following main advantages:

- Short gestation period.
- Availability of infrastructure.
- Closeness to the load centers.
- Required civil works are fully or at least partially developed.

In addition to above advantages, the following points are also very important in the overall cost of the project and hence lower tariff.

4.1 Hydro-Logical Risk

Where seasonal rainfall affect the amount of water available to a hydropower station, generation may fall below average levels during dry seasons. The fall of generation due to flow variation is known as hydrology risk and is taken care of through power purchase agreement. Low head projects are generally free of this type of risk because of reliable flows at barrages and canal falls. Flow data is available for more than 30 years. Therefore, sponsor and power purchaser may not worry about hydrological risk. In Nepal, flow data of 28 years is considered reliable and Government is not responsible for hydrological risk.

4.2 Attractive to Private Sector

Under May 1995 hydel policy and Policy for New Independent Power Producers, July 1998, the Government of Pakistan is envisaging for privatization of all types of hydropower projects in the country.

The Government of Punjab has offered 45 sites with installed capacity of 286 MW in private sector. The available head varies between 0.61 to 8.5 m. Out of these sites, about 27 sites have head less than 2.5 m. About 10 sites are along non-perennial canals. Sites at Jinnah, Taunsa and C-J: Link Tail was also offered to private sector. The Government of Azad Jummu and Kashmir has also offered one low head site having capacity of 45 MW in private sector.

The response from the private sector was very encouraging and allocation of sites was thus made in a short period. Total of about 41 Letter of Intent (LOI) and Letter of Support (LOS) have been issued by PPC of Punjab, N.W.F.P and AJ&K having capacity of 1838 MW. Out of these about 26 LOI were for low head projects with a total capacity of 560 MW (**Table 9**). It is important to note that only 3 sites were studied up to feasibility level and the rest are only at identification level and about 9 sites can not be developed due to head less than 2.5m. This encouraging response from the private sector in low head projects compared with projects in other parts of the country, especially NWFP and Northern area, may be due to better accessibility, no obstruction due to snow falls/rain, easy connection with national grid, safety/security, developed area and better acceptance by the local population. It is pointed out that out of 8 projects investigated up to feasibility level by SHYDO, only 5 projects got LOI in NWFP. No project up to identification level in NWFP and Northern Area got LOI/LOS. However, there are 13 sites left (Sr. No. 1 to 13) in **Table 9** for which the LOI/LOS is still valid.

It is pointed out here that not a single project has achieved financial close up, due to reasons unknown to the authors of this paper.

4.3 No Scioeconomic or Environmental Risk

For a successful and financeable hydropower project, the issues related to environment and socioeconomic such as inundation of agriculture land, disruption of fisheries, riverbed sedimentation, expropriation of land, population resettlement and negative publicity are very important. In case of low head projects, issues such as resettlement, inundation of agriculture land, sedimentation and expropriation of land do not apply because the irrigation infrastructure already exist.

4.4 Less Technological Risk

The financing institution concern is the potential that technological factors will lower project performance, and, thus, the likelihood that a hydro plant will not meet its goals. Technological factors include risks associated with unproven or substantial technology, inadequate design, tunneling, sedimentation, seismology, floods, etc. These risks do not relate to low head projects, because total potential is along already constructed structures and canals.

4.5 Less Construction Completion Risk

Construction delays generally cause cost overrun, resulting in increased technical and labor costs, greater interest during construction, development expenses and other indirect costs. The low head projects are less susceptible to construction delays, because the subsoil conditions are well defined, flood damages is negligible, infrastructure is available and of no or very less resettlement and land expropriation problems.

4.6 Require Less Capital

The low head projects mostly having capacity less than 20 MW are not capital-intensive and can be invested even under present national and international financial market conditions. It is totally unrealistic to expect that the international lenders/investors are ready to take risk in large capital-intensive hydel projects under the precarious financial position of our country and the present crisis in the financial markets worldwide.

Table 9. Sites Taken up by Private Sector.

Sr. No.	Name of Sponsor	Location	MW	LOI Issued	LOS Issued
1.	M/s Laraib Energy Block 95, Suite F, 1/7 Blue Area Islamabad	New Bomg Escape	45	6-6-95	18-5-96
2.	Marubeni of Japan 179-A Abubakar Block P.O.Box 484, Lahore	Jinnah Barrage Indus River	144	17-9-96	
3.	M.K. Power Rawalpindi.	B.S. Link I RD 106+000	10	28-6-94	29-8-94
4.	Shaukat Hydel, Fortress Stadium Lahore	B.S. Link I (Tail)	9	3-8-94	11-10-94
5.	Albario Trading Corp. Resul Bidg. 50 Shahrah-e-Quid-e-Azam, Lahore	U.C.C (L) RD 283+100	8*	11-11-96	2-2-97
6	Cogen Technolgies, 1600 Smith, 43 rd Floor Houston, Taxes-77002	Pakpattan Canal RD 112+350	7*	15-3-97	
7.	State Engineering Projectc Co. (Pvt) Ltd. Saeed Plaza Jinnah Avenue, Islamabad	U.C.C (L) RD 128+000	7*	28-2-97	
8.	Pharlap Power, 1st Floor, Centre Point, Gulberg-III Lahore	Main Line U.C.C RD 133+296(Head of U.C.C(L))	5	11-11-96	27-1-97
9.	Independent Energy Partners, INC. Executive Centre, 92 Commercial Area Cavelary Ground Extension Lahore Cantt.	C.J.Link Tail	40	8-7-96	
10.	-do-	Taunsa Hydropower project	120	27-8-96	
11.	-do-	New Bong Escape U.J.C. RD 27+000	45	23-5-96	
12.	-do-	U.J.C. RD 36+860 **	3	23-5-96	
13.	-do-	U.C.C. RD 0+000	10	23-5-96	
14.	-do-	L.C.C (M) RD 0+000 **	5	23-5-96	
15.	-do-	B.S.Link I RD 0+000 **	19*	23-5-96	
16.	International Development company, 116 L, LCCH Lahore Cantt	L.J.C RD 0+00	8.5*	5-7-95	
17.	-do-	Gujrat Br. RD 000-2000	3	5-7-95	
18.	-do-	U.J.C RD 36+660 ***	9*	5-7-95	
19.	-do-	R.Q.Link RD 000 **	8.5*	5-7-95	
20.	-do-	U.J.C. RD 63+000 **	8*	5-7-95	

21.	-do-	U.J.C. RD 34+756 **	10*	5-7-95	
22.	Amin Bros. Engineering (Pvt) Ltd. 19-B DI Gulberg-III Lahore	Q.B.Link RD 271+655 **	9*	20-2-97	
23.	Syed Bhais (Pvt) Ltd,P.O 483, 200 Ferozpur Road Lahore	U.C.C (L) RD 221+000 ***	6	26-2-97	
24.	Amin Bros. Engineering (Pvt) Ltd. 19-B DI Gulberg-III Lahore	Q.B.Link RD 304+985	2.5	20-2-97	
25.	Punjab Power (Pvt) Ltd, IEP Bidg, Liberty Market, Gulberg-III Lahore	L.B.D.C RD 329+056+RD 340 850	4.5	24-2-97	
26.	Power Tek Ltd, 3-Chairman House Road, Faisalabad	Q.B.Link RD 379+265**	10*	23-2-97	

* Power potential is quit higher than HEPO Inventory.

** According to Inventory these falls can not be developed due to head less than 2.5 m.

*** According to Inventory these falls do not exist.

5. OTHER ISSUES OF LOW HEAD PROJECTS

5.1 Policy of WAPDA

WAPDA decided not to consider plants of less than 20 MW capacity and left these projects to the Provincial Government for signing of the purchase agreements, if considered feasible as per decision by the Cabinet Committee on Investment (CCOI). This decision means the construction and operation of small hydels (20 MW and less) would be in isolation which is not practical as no Provincial Government has its own independent transmission and distribution network. This will hold up the development of hydel potential available very close to the load center and the national grid. However, under present state of technological development and use of efficient digital computer made possible and reliable, the operation of interconnected system up to its highest accuracy. Therefore, this policy may be reconsidered for the development of low head projects, since it is very much attractive to private investors and lenders as stated above.

5.2 Tariff and Selection of Small Projects

In 1995 policy the tariff offered for projects less than 20 MW was higher than the projects having more capacity. It was a realistic approach. But in 1998 policy, it is stated that they will be offered a tariff equal to the average levelized tariff derived from competitive solicitations for indigenous resource based projects over the previous 12 months. The above stipulation is not realistic. It should be made on economic criteria and not on financial parameters. Further more each hydel station is site specific and needs to be treated differently, there is no "average hydel power plant". This policy will undermine especially the low head projects, because it is well understood that the energy generation cost of the low head projects is higher than the medium or high head projects. However, their induction into the transmission (at different voltage level: usually at 11 kV and 66 kV) and distribution system is even beneficial.

Low head projects usually, have high investment cost. In some cases these projects do not form a part of the so called "least cost expansion plan". This is basically because the least cost expansion plan is insensitive to the location of the proposed generation facility with reference to the load centers. Low head projects are usually located within the load

centers and the benefits of adding these are best compared by quantifying the long run marginal cost (LRMC) of capacity and energy for the voltage level (usually 66 kV and 11 kV) at which the scheme is contributing power. There is therefore, need to use the LRMC estimates to develop the economic evaluation of low head schemes. Estimates of LRMC are given in **Table 10.** Therefore, the selection of the projects should always be based on long run marginal cost (LRMC) analysis considering voltage level instead of on the basis of generation cost only.

Table 10 Marginal System Costs (Rs/kWh)(1998-99) at Various Voltage Levels

Sr. No.	Level	Capacity $/kW	Peak c/kWh	Off-peak c/kWh
1.	Generation Level	435	3.49	2.98
2.	220 kV Level	563	3.58	3.08
3.	132 kV Level	649	3.67	3.17
4.	66 kV Level	683	3.81	3.26
5.	11 kV Level	786	4.87	3.99

In our opinion these should be compared with thermal projects only, because of their performance in the system. They will replace thermal plants running as base load plants.

It is also very interesting to note that all hydels will offer much less tariff after first 10 years than thermal plants.

Table 11. Tariff of Thermal IPPs

Sr. No.	Project Name	Generation Cost US Cents/kWh				
		1-10	11-20	21-30	1-30	Levelised
1.	Hub Power Project					
2.	Kapco Power Project	5.960	4.860	4.380 (21-25)	5.200 (1-25)	5.600
3.	AES Pak Generation(Pvt.) Company	6.101	4.659	3.500	4.753	5.577
4.	Kohinoor Power Generation Ltd.	6.091	4.020*		4.962 (1-22)	5.551
5.	Japan Power Generation Ltd.	6.010	4.019*		4.450 (1-22)	5.560
6.	Habibullah Power(Pvt.) Company	6.1006				5.5776
7.	Fauji Kabir Wala Power Company	6.100	4.551	4.295	4.982	5.578
8.	Rousch Power Company	5.963	4.780	4.100	4.954	5.578
9.	Saba Power Company	5.743	5.035	5.035	5.271	5.581
10.	Eestateck Limited	6.101	4.538	3.470	4.702	5.578
11.	Southern Electric Power	6.100	4.119	3.470 (21-22)	4.960 (1-22)	5.578
12.	Power Generation System Ltd.	6.101	4.170		5.048 (1-22)	5.577
13.	Liberty Power Project	5.998			5.045 (1-22)	5.578
14.	Davis Energen Ltd.	6.050	4.47	3.570 (21-23)	5.040 (1-23)	5.576

Note : * = 11-22 years

Table 12. Tariff of Hydels IPPs (CCOI)

Sr. No.	Project Name	Generation Cost US Cents/kWh				
		1-10	11-20	21-35	1-25	Levelised
1.	Malakand III	3.5100	1.3252	1.2204	2.1782	2.8990
2.	Jinnah	4.3918	1.5643	1.4451	2.6715	3.6023
3.	Matil-tan	4.9077	1.6172	1.5273	2.9154	3.9925
4.	New Bong Escape	5.0908	1.7078	1.5452	3.0285	4.1451

6. CONCLUSIONS

- Low head hydropower projects in the irrigation system is the pioneer in generating electrical energy in Pakistan. However, during 1960s and 1970s, this was ignored due to development of big hydel projects.
- In early 1980s, it was realized that low head sites in irrigation system of Pakistan have some advantages than big projects like Kalabagh. These have short gestation period, close to load center and civil structures are partially or fully developed. As a result of ranking study, construction of Chashma and Rohri Hydropower project was taken up. It should be followed by other planned projects such as Jinnah, Taunsa, C.J.Link Tail and Guddu for which feasibility reports are ready.
- Other exploitable potential from inventory may be assessed properly, which can play a remarkable roll in the development of the country under private power policy. It should be kept in mind that in the development of new low head hydropower, greater difficulties than in the past are expected because, best sites are already used.
- Low head projects have advantages such as no hydrological risk, no risk of cost overrun due to technological risk, no environmental and socioeconomic problems, need less capital, attractive to private investors due to their locations, etc.
- Less exposure to natural disasters, such as floods, landslides, mud floods, etc.
- Offer better Safety/security due to developed area and better acceptance by the local population.
- Offer better accessibility throughout the year. No Obstruction due to rain or snow falls.
- Low head projects (20 MW) are not capital-intensive and can get financing under prevailing financing conditions, nationally and internationally.
- WAPDA policy not to consider projects less 20 MW is not realistic and needs reconsideration for the development of low head potential which are very much attractive for private investors and lenders.
- Low head projects (20 MW or less) may be having relatively more per unit generation cost, however their induction into transmission (at different voltage level) and distribution system may be beneficial.
- The statement about the offered tariff for low/small hydel projects in 1998 policy may be reconsidered.

- The selection of the low head projects may be based on long run marginal cost analysis.
- The low head projects may be compared with the thermal plants, because of their performance in the system.

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