Main Features of the SHP Sector in China

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1 An important sector in the hydropower industry

Since the founding of the People's Republic of China in 1949, and particularly since the reform and opening up period, rural hydropower has witnessed swift development. Rural hydropower exploitation has been included in the plans for rural electrification development, and has become an important part of the water resources sector. A new SHP industry has formed, combining social, economic and environmental benefits.

With the progress in constructing the rural electrification counties, the scope of the rural hydropower business has been increasing steadily, with wider and wider coverage. By the end of 2001, there were 43,027 SHP stations in the whole country, and the total SHP installed capacity reached 26.262 million kW, representing 31% of the national installed hydropower capacity. Annual power generation was 87.1 billion kWh, representing 33% of the national hydropower output. Rural hydro based county grids in over 800 counties and over 40 inter-county rural hydro networks have been established, with 980,000 km of 10 kV and above high voltage transmission lines, 1.91 million km of low voltage transmission lines, 35 kV and above transformer capacity of 43.02 million kVA and 10 kV distribution capacity of 50.39 million kVA. Half of the territory, one third of the counties and one quarter of the population in China depend mainly on SHP for energy.

According to statistics, the value of SHP assets in China exceeded 150 billion Yuan and the annual revenues from power sales were over 40 billion Yuan. Total annual profit and taxes were more than 7 billion Yuan.

Currently, around 1.2 million personnel in China are engaged in the SHP industry, of whom 300,000 are design and construction staff. There are over 100 SHP equipment manufacturers with annual production capacity of 1,500 MW.

2 An important energy source for rural electrification

There are usually three channels of energy supply for the implementation of rural electrification:

- Extension of the state grids.
- Diesel energy or other thermal power.
- Local decentralized renewable energy (SHP, solar power, wind power and biomass etc).

It would be generally uneconomic for the state grids to be extended to reach the remote and decentralized rural population.

Dependence on diesel energy or other thermal power is costly and sometimes unreliable, as fuel supply and equipment maintenance are difficult.

In comparison with wind power and solar power, SHP technology is proven and commercialized, with low construction and operation cost. A complete industrial system from R+D, design and manufacturing to construction has been established, and the key technology is mature. The per kW cost ranges from 5,000 to 8,000 Yuan which is much lower than that of wind power or solar power. Presently, SHP generation accounts for over 97% of the total renewable energy production. Both the power generation and the quality of SHP are superior to other renewable energies. Table1 compares the production cost of SHP, small thermal power, diesel power, wind power and solar power. SHP has the lowest cost.

Table 1 Comparison of production cost of SHP and other energies

Generation type	Per kW investment (Yuan/kW)	Fuel cost (Yuan/MW.h)	Energy Production cost (Yuan/MW.h)
SHP	5,000~8,000	0	5~10
Diesel power	2,500~3,500	20~35	35~50
Small thermal power	3,000~4,500	15~25	25~35
Wind power	10,000~15,000		30~100
Photovoltaic	20,000~30,000		100~300

As one type of renewable energy, rural hydro energy in China has the following features:

(1) Abundant resources. The exploitable resources of SHP in China amount to 120 GW, representing 31% of the total hydropower potential in the country, and is listed as the highest in the world.

(2) Wide distribution. The exploitable SHP resources are distributed in 1573 counties. Over60% of the total are located in the west part of China; and around 30% of the total are in the central and east parts of China. SHP resources are more available and popular than coal or oil resources, and play a unique role in the promotion of the economy in China's western region.

(3) Flexibility in exploitation. SHP can be exploited in a decentralized way, forming its own grids to supply energy. In terms of capacity, SHP can range from a few kilowatts to tens, hundreds, or even tens of thousands of kilowatts. It can supply energy to households, villages, townships (towns) and counties (cities), with high adaptability and 'radiation' effect. Furthermore, SHP is small in scale and so needs less funding. The exploitation technology is mature, the construction period short, only simple maintenance is required and operation costs are low. The exploitation of SHP in poverty-stricken areas is more economically and technically feasible than that of medium and large hydro or thermal power. We can say that whereas the State collects funds to develop big power generation projects, the local governments are most suited to developing SHP.

As a developing country, China has a rural population that represents around 70% of the total population. Thus, the average rural energy consumption per capita is low and electricity accounts for a low proportion of total rural energy. Development of rural electrification, making full use of local hydropower potential and constructing SHP stations are the basic conditions required to ensure the sustainable development of the rural economy.

3 Salient social and economic benefits

Social and economic benefit is a comprehensive concept. Social benefit is a type of public welfare benefit and has an important role to play in macro decision-making. Economic benefit can be subdivided into macro-economic and micro-economic benefit. The former is associated with comprehensive benefits of the national economy in one province or region while the latter usually refers to the financial benefits of the SHP station itself.

The salient social and macro economic benefits of SHP in China are the key prerequisites for the swift and large-scale development of SHP in the past few decades. Since the founding of the People's Republic of China in 1949, the government, finding itself in a situation where there were very limited central funds and where the national grid had limited reach, adopted the strategic principle of unified planning and guidance, and encouraged the local authorities to take an active role in developing SHP stations. Local funds were mobilized, and the local people participated in the labour force. By gradually implementing rural electrification so as to boost local industry and improve the income of the farmers, energy supply to half of the territory was provided in a short period. As a result, the material and cultural life of the local population was improved and more job opportunities created. Also, the ecological environment was improved and tourism stimulated. In the central and western parts of China in particular, rural hydropower has become an important pillar of regional economic development. Rural electrification experts in many countries consider that, in appraising the social and economic benefits of SHP, the comprehensive benefits that the end-users (including individuals and groups) obtain should be one of the important evaluation parameters, as electricity is a kind of intermediate product and demonstrates its social and economic benefit through the use of electrical appliances and machines. It is still very difficult at present to quantify many of the social and macro-economic benefits. Before the period of opening up and reform, micro financial analysis was not done seriously. If the annual revenues of a SHP station which was invested by the State and locally mobilized funds could just cover all expenditures and hand over some profit and tax, then such a project would be considered feasible. Many of them did not pay attention to the return period of the investment or the financial benefit. However, the financial analysis of SHP construction has gradually become an important consideration during the last 20 years or so.

(1) Analysis of the social and macro economic benefits. Nearly all the social and economic impacts of SHP are positive. The intended impacts, which are often mentioned by the international community when discussing the social and economic impacts of SHP, have become actually realized benefits during the course of China's practical experience over the past few decades. To summarize, they are as follows:

● Increased development of local industry. The development of local industry (called township enterprises in China) is significant for the rural areas. "There could be no stability without agriculture, and no wealth without industry" is the simplest description of economic development in the rural regions. In the 1950s, when the countryside was at a preliminary phase of development, food was the first important consideration. In later decades, local industry became more and more important and electricity almost became the "golden key" to wealth in the hilly regions. According to statistics, consumption of one kWh would create a production value of 3~7 Yuan in a rural enterprise in the 1980s; during the later period of the 1990s the production value could reach as high as 10~30 Yuan. For instance, the total SHP output in 1996 was 61,960 GWh, 57.1% of which was used in industry. So, the role that SHP played was quite obvious.

Before the construction of the first batch of pilot rural electrification counties, the proportion of industrial production value in the total industrial and agricultural production value in these counties was only 36.6%, a typical value for rural counties. After 5 years implementation of the county rural electrification programme, the proportion in this first batch had increased to 60%. In 2000, the figure was further increased to 77.5%.

During the 5 years of implementation of the second batch of pilot rural electrification counties, the proportion of the industrial production value in the total industrial and agricultural production value was increased from 56% to 69%, and in 2000 it reached 77%.

● Increased income of the farmers. Taking as an example the three batches of the pilot rural electrification counties, the average income of the farmers tripled during the 15 years of implementing the rural electrification counties programme, indicating the social and macro economic benefits that SHP could bring were enormous. Table 2 shows some concrete data.

● Increased modernization of agriculture. SHP has mainly been used for agriculture, by-product processing, forage and husbandry processing. According to preliminary statistics, by the end of 2001, the capacity in MW of various types of electrical equipment used in rural areas below the county level is as shown in Table 3.

Table 2 Increase in Farmers' Income due to Rural Electrification

	Increase in the average net income of the farmers (Yuan)	Annual average growth rate (%)	Annual average growth rate in the whole country (%)
The first batch of 109 rural electrification counties (1984~1989)	203 → 2,303	8	4
The second batch of 209 rural electrification counties (1990~1995)	548 → 1,150	10	5
The third batch of 335 rural electrification counties (1996~2000)	1,082 → 1,914		

Table 3 Capacity (MW) of Electrical Equipment used in Rural Areas Unit: MW

Year	Drainage & irrigation equipment	Agricultural production	Agricultural byproduct	Town & township enterprise	Domestic lighting	Others	Total
2001	4,296	1,862	5,000	26,453	18,150	5,562	61323

According to a rough estimation, the energy output from each kW of electricity is approximately equal to that of 5 ordinary farmers. The capacity used directly for agricultural production from the above table is close to 20,000 MW. If calculated at a load factor of 40% (equipment is not all used at the same time) the effective power capacity is 8,000 MW, equivalent to 40 million rural workers. Rural electrification and mechanization has promoted the modernization of agriculture and reduced the number of farmers engaged in agricultural production, promoting their transfer to the cities to provide their services for urbanization. In fact, some

150~200 million farmers (approximately half of the total 380 million farmers in China) had transferred from agricultural production to the secondary or tertiary industries by the end of 1996.

In addition, electrical drainage and irrigation are also an important aspect of agricultural modernization and can obviously increase food production. Currently, the area under electrical drainage and irrigation is 30 million hectares. If each hectare could produce 1,000 kg more food on average, an annual increase of 30 billion kg could be achieved.

● Improved living standards of the rural people. Around 91.73% of rural households are now able to use electricity. With the availability of TV and tape-recorders, cultural life is enriched and people can enjoy more opportunities to receive education.

● More job opportunities created. Construction of SHP projects is a labor intensive and long-term process, and a large number of technical and non-technical staff is needed, with frequent technical training. With the development of SHP, around one million staff are currently engaged in the SHP sector.

● Development of tourism. Many SHP stations are in scenic areas. After the construction of SHP stations, many such scenic spots have been open to the public. That not only provides sightseeing spots for tourists, but also increases the income of the SHP station.

(2) Economic benefit analysis. Since the 1980s, the State has adopted a policy of opening up and reform, and moved towards a market-oriented economy. The financial analysis of SHP stations is gradually receiving attention. All the funds, no matter where they come from - the central government, the local governments, and bank loans or from the mobilized funds of the local people -are invested after careful analysis of the financial benefit. The financial return is the decisive factor for private or foreign investors in particular.

In 1995, the Chinese Ministry of Water Resources formulated and promulgated the <Economic Appraisal Norms for Small Hydropower Project Construction> (called Norms hereafter) which was used as the sectoral norm of the P.R. China and implemented throughout the whole country. The <Norms> give detailed instructions on economic appraisal for the construction of SHP projects below 25 MW in installed capacity. Actually, economic and financial analysis has been required for SHP stations in the past 20 years. After the promulgation of the <Norms>, this analysis has become more standardized.

In the financial analysis, the input and output are the two basic parameters. What concerns investors the most is the investment return, the payback period and the amount of profit. In accordance with international practice, the <Norms> stipulates that the financial internal rate of return for the construction project should be greater than or equal to 10% for it to be financially feasible. According to the general understanding, the turn period for investment should be less than 10 years.

Some brief remarks follow regarding the main parameters of financial analysis for SHP construction projects: A) investment; and B) the annual effective power output and the selling price:

● Investment. This is usually expressed as the cost per kW. The figure could vary greatly according to different periods, place and project. Table 4 shows the rough range of variation of the parameters in the past 30 years:

Table 4 Cost of SHP Investment (Yuan/kW)

	1970s	1980s	1990s	2000-
Per kW cost of investment for SHP construction projects (Yuan/kW)	1,000~2,000	1,500~3,000	4,000~9,000	5,000~8,000

Whether the investment is big or small depends on various factors. Generally speaking, the higher the head, the lower the cost per kW of the project. The design complexity of the project such as with dam or without dam also exerts a big influence on the investment. The high per kW cost of 9000 Yuan/kW reached in the 1990s was influenced by price fluctuations. Currently, the cost per kW has dropped to some

6000 Yuan/kW, in line with the drop in the price index.

●Output. The main parameters are the effective power production and the selling price.

In accordance with the requirements of the <Norms>, the economic benefit or power generation (supply) benefit of the SHP projects is quantified for calculation and is defined as income.

Income from the power sales=Effective energy amount ×(1-S%) (1-T%) × the selling price

The effective energy refers to that part of the design power output that can be utilized by the end-users. This is different for every SHP station and can vary from 60 to 100%; S% refers to the percentage of power output required for the station's own-use; T% is the transmission line loss ratio, around 10% on average in China, with some areas even higher.

● Annual utilization hours. The annual utilization hours (also called the plant factor internationally) is another parameter used to express the annual power output. The annual utilization hours are relatively low in China and need to be improved in future. Table 5 illustrates the average annual utilization hours of SHP stations during the past 20 years in China.

Table 5 shows that the average annual utilization hours in the 1980s were only 2,000 h or so. Though it has increased from decade to decade, it was only 3,458 h in 2001, equal to a plant factor of only 39.4%, which is much lower than the average figure of the international community.

● Price. For a long time, the low selling price to the grid has been an important factor affecting SHP development. The selling price of SHP to the grid in many areas remains below 0.20 Yuan/kWh due to various factors. In recent years, the price has increased to 0.30 Yuan/kWh in some areas under the joint efforts of the local governments in some provinces, thereby improving the benefits from SHP.

The annual utilization hours and the low selling price of SHP to the grids are the main factors for the low financial return of SHP stations in the past 10 or 20 years.

● Generation cost. According to the <Norms>, the generation cost includes depreciation, the annual operation cost (including wages, welfare, water fee, repair fee and other expenditures), shared allocation cost and interest. The standards of each cost are stipulated clearly in the <Norms>.

Owing to many factors, the generation cost of SHP stations in China is currently still high, in the range 0.05-0.10 Yuan/kWh, and this too affects the economic return.

The <Norms> gives concrete regulations for uncertainty analysis in the economic appraisal of SHP construction projects, including sensitivity analysis, breakeven analysis and risk analysis. For simplicity, this book does not provide further details.

●Simplified case study for calculating financial return. Take as an example a SHP station of 10 MW, with a construction cost of 6,000 Yuan/kW, total investment 60 million Yuan, annual utilization around 3,000 h and annual power generation 30 million kWh. For simplicity, the saleable energy is assumed to be 30 million kWh (the saleable energy is less than the effective energy and the actual effective energy is less than the annual energy). If the selling price of electricity to the grid is taken as 0.3 Yuan/kWh, then the annual income from electricity sales is 9 million Yuan. The generation cost is taken as 0.08 Yuan/kWh, so the total cost will be 2.4 million Yuan and the gross profit before tax is 6.6 million Yuan (Various taxes and interest will have to be deducted in practice). Following this estimation, FIRR is around 10-11%, i.e. the payback period is less than 10 years. This complies roughly with the criteria stated in the <Norms> and is acceptable to investors.

Table 5 Annual Utilization Hours

	1980s	1990s	2000-
Annual utilization hours	1,700~2,800	2,800~3,200	3,300~3,400

● Comparison of various annual utilization hours and number of years for the payback period.

Based on actual conditions at present, the Table 6 compares various parameters to show the limits acceptable to investors.

As mentioned above, this estimation ignores many factors. The actual benefit is lower than that listed in Table 6. According to this estima-

Table 6 Comparison of financial estimation for SHP Plants (Based on unit cost 6000 Yuan/kW)

	Selling price to the grids(Yuan/kWh)			
	0.25	0.30	0.35	0.40
Annual utilization hours 2000 h				
Annual energy per kW (kWh)	2,000	2,000	2,000	2,000
Income from sales per kW (Yuan)	500	600	700	800
Annual generation cost (Based on 0.05-0.10 Yuan/kWh)	100-200	100-200	100-200	100-200
Gross profit before tax (Yuan/kW/Year)	400-300	500-400	600-500	700-600
Payback period(Years)	15-20	12-15	10-12	8.5-10
Annual utilization hours 3000 h				
Payback period (Years)	10-13.3	8-10	6.6-8	5.2-6.6
Annual utilization hours 4000 h				
Payback period (Years)	7.5-10	6-7.5	5-6	4.3-5

tion, if the unit cost is 6,000 Yuan per kW for a SHP station, the annual utilization over 3,000 hours, and the selling price of electricity to the grid is over 0.3 Yuan per kWh, then the period of return is 8-10 years, roughly in line with the <Norms>, and acceptable to investors. If the annual utilization hours are 2000 h, then the selling price of electricity to the grid must be over 0.35 Yuan per kWh. If the selling price of electricity to the grid is 0. 2 Yuan per kWh, the annual utilization hours must be over 4000 h to be profitable.

At present, there are over 4,000 SHP stations each over 500 kW in installed capacity. The construction time and the cost vary. The selling price to the grids in different places also varies from over 0.3 Yuan to below 0.2 Yuan. Thus, the benefit is quite different and it is difficult to make detailed studies and statistics. Roughly speaking, those built before the 1970s earned little profit and many of those built after the 1980s earned no profit. Since the beginning of the 21st century, many of the newly built or planned SHP stations comply with the requirements of the <Norms>. The main reason is that some areas were successful in increasing the selling price and reducing the unit cost. For example, private investors in Zhejiang province have been very active in investing in SHP stations in recent years. Since 1993, the shareholding system and private investment for SHP stations represent over 80% of the newly installed capacity each year. In Wenzhou, Zhejiang province, the unit cost has been reduced to below 5,000 Yuan per kW for many SHP stations and the selling price to the grids reached 0. 30-0.50 Yuan per kWh. The economic benefit is obvious. In recent years, SHP potential has also been actively exploited in mid- and west China. The People's Congress of Guangdong province issued resolutions in 1996 and 2003 respectively for speeding up the construction of SHP by promulgating preferential SHP policies that increased the selling price to grids from below 0.2 Yuan per kWh to over 0.3 Yuan per kWh. This policy not only promoted SHP development but also helped lots of SHP stations to survive.

Nevertheless, the mechanism of determining the SHP selling price to the grids is still not very satisfactory and the construction investment is still high. In addition, some designs are not optimized and there is a low level of management and low financial benefit. SHP development is confronted with a lot of obstacles .

4 Positive environmental benefit

The use of all types of energy resources influences the environment and exerts some negative impact in one form or another. For example, the burning of fossil fuels such as coal, oil and natural gas produce pollutants harmful to the environment and to human health. Although these factors could be alleviated through some technical measures, air pollution causes the greenhouse effect, acid rain, and aerosols, leading to various respiratory diseases. There is an issue of balance between the advantages and disadvantages, whichever type of energy supply is to be selected as the most appropriate.

As most of the areas rich in rural hydropower resources are located in natural forest areas, natural protection areas or areas severely eroded by water and soil, the exploitation of rural hydropower in these areas would replace burning of firewood, coal, or gas and hence reduce the degree of damage to the environment caused by farmers and reduce the consumption of non-renewable fossil fuel resources, thereby playing an active role in protecting the ecological environment. The total power generation by SHP in 2001 reached over 87 billion kWh, equivalent to 5, 000 million tons of standard coal, and equivalent to a reduction of 950,000 tons of sulfur dioxide, 96 million tons of carbon monoxide, 400,000 tons of nitrogen chloride, 120 million tons of carbon dioxide and other pollutants such as wastewater and sewage. In terms of timber, the electricity produced by SHP yearly could save 4-5 million m^3. In fact, in all the SHP and grid connected areas, the previous large scale felling has been reduced and the forest coverage steadily increased, due to the widespread replacement of firewood burning with electricity. The ecological environment has been protected with great ecological benefit.

As SHP stations are numerous and widely scattered throughout the country, SHP has a special role to play in improving the environment, with the following main features:

(1) It is beneficial to forming a clean rural energy structure. It is a major reform to change the tradition of burning firewood for cooking. The policy of “electricity to replace firewood” plays a positive role in preventing the reduction of forest area and improving hygiene conditions in rural areas. China has developed electric cookers widely in the SHP supply areas. The policy that China has adopted is the coexistence of electric cookers and firewood-burning stoves, i.e. in the flood season, the electric cookers are used; in dry periods, the firewood stoves are used. In many places, the price for using electric cookers has been reduced to only 5-8 cents Yuan per kWh, merely one third or one quarter of the price for domestic lighting. According to statistics in Sichuan province, a family of five members would burn 2,500-3, 000 kg of firewood annually. Around 300 million people inhabit the SHP supply areas in China. Without electricity, firewood burning would definitely cause an environmental disaster. As reported, in a village of northwestern China, the locals chopped down trees and dug out the grass roots, so that water resources were severely damaged. Finally, the whole village had to migrate elsewhere. When mankind damages the environment, they will in turn be punished by it.

(2) The ecological environment is improved in rural areas. The practice in China shows that the multiple development of SHP in combination with small basin comprehensive treatment and water and soil conservation is a very efficient way of improving the local environment. For example, a small basin called Hujiahe in Anhui province has an area of 253 km^2. Due to over cultivation and felling, the water and soil there suffers severe erosion and the riverbed elevation has increased, causing floods and water logging. Rice production has fallen, thereby causing farmers to chop down the remaining forest for arable land to grow rice. Finally, the farmers have no firewood to cook the rice and have to dig up the roots or turf for cooking. After the treatment of the small basin and the construction of a 50 km transmission line, 90% of the rural households could enjoy the use of electricity. The development of SHP and the application of biogas plus the use of firewood-saving stoves alleviate the pressures due to the shortage of rural energy. Currently, there are no barren hills to be seen in the basin, the problem of water and soil erosion is being solved and the natural environment has improved considerably.

(3) Natural disasters are mitigated. Poverty is the greatest cause of damage to the ecological environment. If combined with flood prevention and irrigation, SHP can play a role in disaster mitigation, in addition to promoting the local economy and improving the local environment.

As the development of SHP requires the construction of roads, transmission lines and dams, it may affect the existing environment for animals or plants. However, it may be compensated by the increase in the resource utilization ratio and the benefit gained from social aspects. Generally speaking, the construction of SHP stations does not need the construction of a large reservoir and it does not involve the large-scale relocation of people, potential silting or changes in the river regime associated with large hydro projects. If other measures are taken, an overhead transmission line may not have to be put up, reducing the impact on the natural scenery. In short, if compared with its benefits or with the impact of other energy options, the environmental impact of SHP stations is rather small.

5 SHP-based local grids

Different from other countries, China paid attention to the development of SHP's own supply areas during SHP construction and some counties formed county grids or trans-regional local grids. The scale of the local grids is usually around 30-80 MW. Presently in China, around 68% of SHP installed capacity and 69.8% of annual power generation is connected to local grids. The process of SHP connection to the grids went through four phases:

(1) In the initial period, after the development of a single SHP station, power was simply transmitted to the users and supplied energy locally, being an integration of power generation and supply.

(2) With the increase in the number of stations combining power generation with supply, a number of such SHP stations within a county were connected together so as to form grids linking several towns.

(3) With a stable increase in the scale of exploitation and the constant development of rural electrification, the town and township grids within a county needed to balance power and energy, and have unified planning for the grids. Thus, grids with unified power generation and supply in a county were formed. Some of the county grids were connected with the State grids, realizing the exchange of energy with the State grids.

(4) In some remote and hilly areas, the grids in several counties were connected with each other to form trans-county local grids so as to increase the ability to generate and supply and to increase the reliability of the supply. By the end of 1999, there were over 40 such local grids with SHP self-generation and self-supply, the largest of which covered over 10 counties (cities).

In addition, the relationship between the SHP stations and the large grids can be summarized as one of the following three types .

- The stations connect directly with the State grid and transmit all of their energy output to the grids;
- Exchange of energy through connection of the small grids to the large grids;
- There is no relationship with the large grids and the SHP stations operate within isolated grids and exchange among themselves, with all the energy consumed locally.

After decades of construction, China's local grids have reached a considerable scale within the SHP supply areas. In the 2,300 or so counties in China, over 1,500 counties have built and operate SHP stations and established local grids of various sizes. In 2001, the number of counties where the grids are managed by the water resources sector reached 505, with a total energy production of 96.67 billion kWh. The annual profit and tax amounted to 4.47 billion Yuan, which is a considerable economic benefit.

6 Unique management mechanism

Different from other countries, the development of SHP in China relies on the local levels and has a decentralized mode. Apart from the strategies, policies, objectives and standards promulgated by the central government, planning, development, operation, management and manufacturing are all implemented by the local governments. SHP has evolved based on the three features of being "local, micro and of service". It has relied on the principle of "walking on two legs", i.e. self-reliance in building SHP stations by the local force as the major source and the supply of energy with the expansion of the large grids. In this way, a county-based and decentralized management system has been formed, such that rural electricity in China is supplied by the large grids, local grids and isolated SHP stations.

The responsible administrative organization for SHP development in China is the Chinese Ministry of Water Resources which has specifically set up the Bureau of Rural Hydro and Electrification to be in charge of the sector, leading the functions of SHP resources planning, construction and management. The SHP administrative bodies at all levels are quite sound. Each province, prefecture and county have their own SHP administrative entities responsible for SHP planning, design approval, construction management and other work at their respective government level. In addition, the Chinese Ministry of Water Resources and local water resources bureaus all have their own hydropower planning & design institutes and scientific academies, responsible for basin planning and R+D on new technology and materials. Based on the funding source and the size of the project, the listing of SHP projects is approved by the planning commission and water resources bureau respectively at the same level. The design, approval and construction of the project are managed by the water resources bureau at each level.

One may refer to the features of SHP development and management in China in comparison with other developing countries. As shown in Table 7, in other developing countries, the solution of the rural energy supply problem is considered as the basic responsibility of the central government. The development and management of SHP in these countries are usually under the direct leadership of the central government. The local governments and people are not involved. According to the United Nations, around 2 billion people in the developing countries do not have access to electricity so far and in some countries the proportion of rural households with access to electricity is only 5%. A small number of the electrified rural households are essentially supplied by extension of the large grids, and some supplied by isolated SHP stations. Therefore, such a centralized mode of management structure is not appropriate for rural hydro development.

Table 7 Comparison of SHP development & management modes

Comparison content	China	Other developing countries
Management mechanism	County as the basic unit; in a decentralized mode of development and management	Under the direct central leadership for project implementation and management
Participation by the local government and people	Directly responsible for planning, construction, operation and management etc	Minimal participation
The relation between power generation and supply	There are local grids for unified generation and supply within the SHP supply areas	Mostly extended by large grids and some supplied by isolated SHP stations

7 Various channels for raising funds

The main source of funds for SHP development in China is from mobilization at the local level, assisted by the State, with multi-channel, multi-layer and multi-mode funding. Before the 1980s, there were mainly two channels for funding: one was from government allocation and the second was from the input of labour by the local people. After the 1980s, there was a trend towards multiple forms of funding. In terms of finance, there was a change from simply getting a loan from the Agricultural Bank to mobilization of funding from many specialized banks and non-banking institutions. Meanwhile, foreign banks and private investment were introduced and the investment modes included loans, joint ventures, wholly foreign-owned companies and BOT (‘build, operate and transfer). Other forms appeared such as community investment in SHP, the shareholding system and the share cooperative system. A group of hydropower joint stock companies with good financial performance has been listed for financing.

In short, fund raising for SHP development in China includes the following ways:

- Encourage the farmers to invest individually or as a group, also encourage enterprises to invest, and adopt a policy of “Those who invest will have ownership and benefit”. In some counties, it was common practice to calculate the man-days of labour contributed by farmers in constructing the SHP stations and the power grids and treat them as a form of capital as well.
- Adopt the shareholding system or the share cooperative system for fund collection or financing, including the use of non-governmental capital and foreign capital. Since the early 1990s when some regions adopted the shareholding system to develop SHP, over 80 SHP stations and grids have been constructed in this way and over 300 SHP stations have been constructed by means of the share cooperative system. This mode is beneficial for the mobilization of SHP funds. For instance, Zhejiang is a leading province in utilizing non-governmental funds for developing SHP. After SHP development was opened to accept non-governmental

capital in 1994, funds for SHP development mainly came from non-governmental sources. After 1994, 11 billion Yuan of funds have been invested in newly constructed SHP stations, (or a yearly amount of 1.37 billion Yuan on average,) of which 8 billion Yuan were from non-governmental sources, (or a yearly amount of 1 billion Yuan on average).

●Adopt the policy of "Electricity supports electricity". The local state-owned SHP enterprises enjoy tax exemptions and can re-invest their profits in SHP reconstruction and so continue rolling development. Due to decades of development, many counties have their own SHP stations and grids and each year there is a certain amount of profit and funding available under the "Electricity supports electricity" policy which can be used for redevelopment. In 1996 the "Electricity supports electricity" funds reached 480 million Yuan.

●Government support. From the central to the local governments, hundreds of millions of Yuan are allocated for SHP development every year. The repayment period for the low-interest loan is usually ten years.

●Loans from financial institutions. The financial institutions have gradually become the main funding source in the past ten years. The Agricultural Bank and the Construction Bank set up specific loans for rural hydropower development to support local SHP construction.

Taking an example in 1996, all the funding channels are listed inTable 8: ■

Table 8 The funding channels of SHP

Funding channel	Capital amount (billion Yuan)	Proportion of the total investment(%)
State investment	0.85	5.87
of which:		
Central government	0.403	
Rural subsidy	0.211	
Hydropower construction	0.236	
Bank loans	6.519	44.99
of which:		
Agricultural bank	2.855	
Industrial & Commercial bank	0.662	
Construction bank	2.202	
Others	0.8.0	
Self-raised funds	4.221	29.13
of which:		
Province	0.530	
Prefecture	1.097	
County	2.594	
'Electricity supports electricity' programme	0.482	3.33
Power construction	0.397	2.74
Using foreign funds & others	2.022	13.95
Total	14.491	100.00

Digested from ***Rural Hydropower and Electrification in China***
Edited by Hangzhou Regional Centre (Asia-Pacific) for Small Hydro Power (HRC)
Published by ***China WaterPower Press***
For further information, please visit
www.hrcshp.org
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Email: shpnews@hrcshp.org

Small Hydropower Resources in China

Hangzhou Regional Centre (Asia-Pacific) for Small Hydro Power (HRC), Hangzhou, China.

In China, hydropower stations with installed capacity under 50 MW are generally classified as SHP. The theoretical SHP potential in China is 170 GW, with 120 GW as economically exploitable, or 72 GW if only stations below 25 MW each are considered.

Fig. 1 below shows the provinces with total SHP capacity over 800 MW.

Fig. 1 Table showing provinces with total SHP installed capacity over 800 MW

No.	Province	Capacity (MW)	No.	Province	Capacity (MW)
1	Guangdong	3,576	7	Zhejiang	1,872
2	Sichuan	3,529	8	Hubei	1,465
3	Fujian	3,057	9	Guangxi	1,407
4	Yunnan	2,250	10	Jiangxi	1,180
5	Xinjiang	2,114	11	Guizhou	958
6	Hunan	2,033	12	Chongqing	839

The main features of SHP in China are big potential and uneven distribution. Among the 2,300 counties, there are 1,104 counties with exploitable SHP potential over 10 MW, (of which, 470 counties each have 10—30 MW£¬500 counties 30—100 MW£¬and 134 counties over 100 MW). So, in terms of hydropower resources, nearly half of the counties in China could rely on SHP for primary rural electrification. Regarding the uneven distribution, SHP is mainly scattered in the hilly, minority areas or the old revolutionary regions, which are vast and sparsely populated with scattered load demand, and where it is hard and uneconomic for the state grid to reach. Thus, SHP plays a vital role in such areas for forming local grids and supplying energy for the local people.

The whole country can be divided into four different regions with respect to SHP resources as follows:

(1) Yangtze River basin and regions to the south.This region includes 10 provinces, i.e. Fujian, Zhejiang, Jiangxi, Hunan, Hubei, Guangdong, Guangxi, Sichuan, Yunnan and Guizhou. They cover mostly mountainous regions with abundant rainfall and steep riverbeds. The exploitable SHP potential accounts for around 40,000 MW, constituting 57% of the nation's total (25 MW stations and below). In the 10 provinces there are 932 counties, of which 749 have over 10 MW SHP resources each. They will be the priority regions for SHP development in the years to come.

(2) Regions between the Yangtze and the Yellow Rivers.These consist of 7 provinces, i.e. Henan, Shandong, Anhui, Shanxi, Gansu, Ningxia, and Qinghai. These provinces are located on the Yellow River plain, the Huai River plain, the Hai River plain and northwest plateau, where the climate is arid and the land topography is gentle, resulting in fewer SHP resources. According to investigations, the exploitable SHP resources in these regions are around 6,500 MW, and there are 135 counties each with SHP potential of more than 10 MW.

(3) Tibet and Xinjiang Autonomous Regions.The two autonomous regions are situated at the foothills of the Himalayas and of the Tianshan mountain ranges respectively. They are richly endowed by nature with abundant hydropower resources. The exploitable SHP potential reaches around 20,000 MW. Nearly all the counties in Tibet and the majority of counties in Xinjiang have more than 10 MW exploitable SHP potential. Thus, they will also be the priority regions for SHP exploitation.

(4) North China and Northeast China Region.There are not many medium and small rivers in this region. Hydropower potential can be found only in a few mountainous areas. The exploitable SHP potential is around 3, 600 MW, representing only 5% of the nation's total amount (25 MW stations and below). Even though small in amount the resources are rather concentrated, mainly in the foothill areas to the east and west of Taihang Mountain, in the eastern parts of Liaoning and Jilin provinces, and in the Daxing'anling forest zones of Heilongjiang province. Consequently, there are still around 100 counties with over 10 MW of exploitable SHP potential each.

Fig. 2 shows the SHP development in 2001.

Fig. 2 Table of SHP Development in 2001 (MW)

Province	Exploitable SHP	SHP Exploited	Ratio (%)	Annual Power Generation (million kWh)
Beijing(BJ)	90.0	45.1	50.1	30.9
Hebei(HE)	939.3	317.3	33.8	304.0
Shanxi(SX)	581.0	151.1	26.0	190.8
Inner Mongolia(NM)	387.0	49.2	12.7	85.3
Liaoning(LN)	429.1	192.9	45.0	373.5
Jilin(JL)	1,887.9	234.7	12.4	599.6
Heilongjiang(HL)	728.0	180.1	24.7	351.1
Jiangsu(JS)	112.0	32.7	29.2	45.9
Zhejiang(ZJ)	3,226.5	1,872.8	58.0	4,693.5
Anhui(AH)	684.5	278.8	40.7	460.1
Fujian(FJ)	3,594.0	3,056.9	85.1	11,540.3
Jiangxi(JX)	3,083.3	1180.3	38.3	3301.4
Shandong(SD)	215.0	78.2	36.4	65.2
Henan(HA)	1,031.0	318.4	30.9	552.0
Hubei(HB)	4,036.0	1,465.7	36.3	3,669.5
Hunan(HN)	4,146.0	2,033.4	49.0	7,198.0
Guangdong(GD)	4,166.0	3,576.2	85.8	11,928.5
Guangxi(GX)	2,322.0	1,407.4	60.6	5,061.8
Hainan(HI)	397.0	216.2	54.5	704.3
Sichuan(SC)	5,878.0	3,528.9	60.1	13,933.0
Guizhou(GZ)	2,554.0	958.5	37.5	3,657.3
Yunnan(YN)	10,250.0	2,250.2	22.0	9,613.6
Tibet(XZ)	16,000.0	158.8	1.0	183.0
Shaanxi(SN)	1,569.0	453.9	28.9	1,036.9
Gansu(GS)	1,089.0	363.6	33.4	1,298.8
Qinghai(QH)	2,000.0	234.4	11.7	837.9
Ningxia(NX)	23.0	3.2	13.9	8.0
Xinjiang(XJ)	3,979.0	662.2	16.6	2,113.7
Total	71,870.0	26,262.4	36.5	87,141.0

Notes:

(1) The exploitable SHP potential 71870 MW is counted on the basis of stations less than 25 MW.

(2) The exploited SHP installation 26262.4 MW is counted on the basis of stations less than 50 MW.

(3) The average percentage of exploitation 36.5% is therefore on the high side and should be lowered to 21.8%, if the exploitable SHP potential is counted on the same basis as the exploited SHP.

Figs. 3,4 and 5 below categorize these by installed capacity, mode of operation and management respectively for year 2001. The micro, mini and small hydropower in Fig. 3.5 refers to installed capacity below 100 kW, 101-500 kW and 501-50,000 kW respectively.

Fig. 3 Table of SHP Stations in 2001 by installed capacity

Type		Micro	Mini	Small	Total
Stations	Number	18,944	19,606	4427	43,027
	Percentage (%)	44.0	45.6	10.4	100
Installed	MW	687	7171	18,404	26,262
	Percentage (%)	2.6	27.3	70.1	100
Annual	GWh	1860	20,245	65,036	87,141
	Percentage (%)	2.1	23.2	74.6	100

Fig. 4 Table of SHP stations in 2001 by mode of operation

Mode		Connected to National Grid	Local Grid	Isolated Operation	Total
Stations	Quantity	4722	20,465	17,840	43,027
	Percentage (%)	10.9	47.6	41.5	100
Installed capacity	MW	6412	17,869	1981	26,262
	Percentage (%)	24.5	68.0	7.5	100
Annual output	GWh	20,097	60,792	6252	87,141
	Percentage (%)	23.1	69.8	7.2	100

Fig. 5 Table of SHP stations in 2001 by ownership

Ownership		State Ownership	Other ownership (Including private)	Total
Stations	Quantity	8244	34,783	43,027
	Percentage (%)	19.2	80.8	100
Installed capacity	MW	17,500	8762	26,262
	Percentage (%)	66.6	33.4	100
Annual output	GWh	62,954	24,187	87,141
	Percentage (%)	72.2	27.8	100

■

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(Continued from page 15) West China is very rich in water resources, but presently the development extent is relatively low, and the per capita power consumption of farmers is less than 30% of the total in China. "SHP replacing firewood" program is an important project for infrastructure construction and protecting the ecological environment in western rural areas, and also an important part for west China's development strategy, which can not only effectively address the issue of farmers relying on firewood, restructure the rural energy, solidify results of the "grain for green" project and the natural forest protecting project, but also plays an important and significant role in improving social productivity of rural areas, realizing agricultural and rural modernization, shortening the gap between middle China and east China.

■ *By Lin Ning*

Five Significant Points of "SHP (Small Hydropower) Replacing Firewood" Ecological Protection Project

Developing rural hydropower and enforcing "SHP replacing firewood" ecological protection project are deemed very significant to protect and improve ecological environment, promote socioeconomic development of rural areas and rapidly build a well-being society in full swing in China, which can be elaborated in the following five aspects:

I. To provide farmers firewood for living use and guarantee a smooth construction of China national key ecological project

Steep slope reclamation, enterprises' over-deforestation and farmers' destruction on vegetation result in worsening water & soil erosion, land desolation, river and lake silting and frequent flooding, which not only deteriorates the ecosystem of mid and west China, and prevent these areas from shaking off poor & backward situation, but also imposes threats upon flood control & disaster mitigation, safety of ecological system and socioeconomic development in east China region. In China, large-scale ecological environment construction with the "grain for green" project as the key part, effectively curbs steep-slope reclamation and over deforestation, but the issue of providing fuel to rural farmer still needs to be addressed, and this issue becomes the main reason leading to serious deforestation.

According to an investigation, during the 1990s the amount of firewood for farmers' living accounts for 40% of the total forest consumption in China, and in some hilly areas the proportion is as high as 50%-70%. The State Council approved that during the "10th Five-year Plan" period, in China the annual deforestation would be restricted to 223 million m^3, among which, the firewood for farmers limited to 64 million m^3. However in 2001, the actual timber consumed by rural residents amounted to 228 million m^3, which is not only much more than the firewood limit for farmers, but also exceeds the limit of total allowed deforestation in China. At present, in China there are about 200 million more rural residents mainly living on firewood for cooking and keeping warming, which seriously threatens the successes of the "grain for green" project and the natural forest protection project. To meet the demands of farmers for firewood becomes the key issue for them to restore arable lands to forests forever.

SHP is of a clean renewable energy, and to implement the "SHP replacing firewood" ecological protection project can permanently and reliably meet the demands of farmers in planned areas for living firewood, which can provide an important support and guarantee to help people return arable lands to forests and step onto a prosperity road. It will not only uproot man-made deforestation, protect forests and retain water resources, but also effectively reduce the emission of greenhouse gases such as CO_2 and other hazardous air SO_2 and CO etc. SHP plays a strategic and significant role for solidifying the results of "returning arable lands to forests" project and natural forest protecting project, and protect & improve the ecological environment.

II. To remarkably clean the atmospheric environment, and keep the promise to the world that China will be committed to protect and improve the global environment

To reduce CO_2 emission is related with the safety of global climate, and it is also a top concern of environment issue in the world. Recently in a report, UNEP (the United Nations Environment Program) points out, a series of severe natural disasters and diseases in Southeast Asia attributes to a 3km-thick brown cloud layer 14km high upon Asian continent, and it poses a devastating threat to the global environment. Firewood consumed by farmers' cooking and warmth keeping is believed the main reason for this brown cloud in Asia. So rural residents in these regions are appealed to develop hydropower and solar energy and other clean renewable energies instead of firewood. A framework treaty of the UN concerning global warming requires that, in the upcoming half century the proportion of present fossil fuel generation in the global power generation, i. e. 80% shall be reduced to 25%

around. Kyoto Protocol stipulates that, by 2012 CO_2 emission of industrialized nations in the world shall be reduced by 5% on the basis of 1990's rate. The annual CO_2 emission in China accounts for 13.6% of the global amount, second in the world. China central government attaches great importance to CO_2 emission, and at the global summit on sustainable development held in South Africa, former Premier Zhu Rongji solemnly declared that Chinese government had already checked and approved the Kyoto Protocol. It is imperative to push forward the development of renewable energies in full swing. SHP is a renewable green energy recognized internationally, and actively developing & using SHP and implementing "SHP replacing firewood" ecological protection project can extremely cut down the emission of greenhouse air, which is an important approach to commit the promise of Chinese government made to the world, that China endeavors to protect and improve the global environment. This conforms to the global development strategy, and it not only meets the urgent need of sustainable development strategy in China, but also contributes a lot to the living and development of all the humankind.

III. To effectively better the farmers' producing and living conditions in hilly regions, and comprehensively promote the construction of a well-being society in rural areas

The key part of the "SHP replacing firewood" ecological protection project is planned in western China's mountainous areas, in which there are 375 national-level poverty-stricken counties, 98 provincial-level poverty-stricken counties, 415 minority-nationality counties and 249 old revolutionary counties. In these areas the social economy is relatively backward, and people's living standard is relatively low. The "SHP replacing firewood" ecological protection project can fully exploit and utilize the abundant SHP resources in these districts, and convert a resources advantage into an economy advantage. While benefiting the "grain for green" project, the natural forest protecting project and protecting & improving the ecological environment, farmer's income can be increased, and meanwhile, industrialization and township transformation of rural regions can be promoted. This is very conducive to restructuring of rural economy and transferring of surplus rural labor force to cities, promotion of spiritual activities and speeding up poverty-relief and prosperity. It is an important strategic means to entirely construct the well-being society and realize the 3rd stage of development target in the new era, and substantially embodies the fulfillment of important "Three Represents" thoughts.

IV. To improve the construction of rural hydropower and other public facilities, the flood-control & drought-relief ability and the capability of water utility serving agriculture SHP is a clean renewable energy that can be recycled for permanent use, which will not threaten the eco environment of river basins, and on the contrary, will reduce the emission of greenhouse air. Furthermore, SHP development can effectively increase the proportion of clean renewable energy in China, and enhance the optimization of electric energy structure. The "SHP replacing firewood" project can motivate medium & small rivers conservancy & development as well as water resources project construction, as to form a virtuous circle of "forests help to store water, water used for power generation, power provided to industries and power benefits forests protection finally". It helps to promote a comprehensive development and sustainable utilization of water resources, and improve a multifunctional water conservancy for the sake of agriculture and rural economy.

V. To remarkably improve infrastructure construction, eco environment and people's living standard in west China, and promote western China's development.

On the 5th Session of the 15th Central Committee of the Party, it is planned that China will make major breakthroughs in infrastructure construction and environment protection in its vast western areas in the next 5 to 10 years. The 3rd Session of the 16th Central Committee of the Party points out, according to strategic deployment of the 16th National People's Congress, the principle of "people oriented" shall be abided by, as well as an all-round, coordinated, and sustainable development view, as to promote a smooth & overall development of regional economy and society. *(Continued on page 13)*

ENROLMENT INFORMATION

2004 TCDC Training Workshop on SHP Equipment（小水电培训）

Sponsored by the United Nations and Chinese government, Hangzhou Regional Center for Small Hydro Power (HRC) aims at promoting the SHP development in the world. China has most SHP stations, with much experience in SHP development. In order to disseminate SHP technology, HRC has already held with success 37 training workshops for 652 participants from over 70 countries.

1. Objectives: To master the basic theory and principles of SHP development, to know more about the serialization and standardization of Chinese SHP equipment, and to master the method of equipment selection, operation and maintenance, etc.

2. Date: From 12 Oct. to 22 Nov. 2004, Hangzhou, P.R. China.

3. Venue: Hangzhou Regional Center for SHP, Hangzhou, China.

4. Course Contents: Procedures of SHP development, SHP Hydrology, civil structure and economic evaluation, SHP equipment selection, operation and maintenance, electrical design and automatic control technology for SHP station, etc.

5. Training Methods: Lectures, discussions, field trips & seminar.

6. Medium of Instruction: English

7. Source of Trainees: SHP personnel or officials worldwide.

8. Methods for Evaluation: Presenting country report on SHP.

9. Participant's Qualifications and Requirements for Admission: The applicants should be under 45 years old, graduated from technical schools with two years' SHP practice, be in good health with no infectious diseases or handicapped, be proficient in English; prepare a review paper or report on SHP development of the participants' country, not to bring family members to the training course, to observe all the laws, rules and regulations of P. R. China and respect the Chinese customs.

10. Training Expenses: The expenses of training, boarding and lodging, local transportation, limited international airfares, pocket money of **RMB 30 Yuan** per person per day for those from developing countries during the training period will be borne by the Chinese government. As the fellowships are limited, those interested are encouraged to apply as early as possible. The expenses of medical care, insurance for the participants are covered by the participants themselves.

11. Application and Admission:

Nominated by their respective governments, applicants are requested to fill up the **Application Form,** which should be endorsed by the departments concerned of their respective governments, and submit with valid **Health Certificate** provided by authorized physicians or hospitals to the Economic or Commercial Counselor's Office of Chinese Embassy (ECCOCE) for examination and endorsement; If endorsed, **Admission Notice** will be issued to the accepted participants by ECCOCE through the related government departments. With **Admission Notice**, participants should go through all necessary formalities with all the mentioned documents to China on the registration date.

12. Insurance: The training course organizer dose not hold any responsibility for such risks as loss of life, accidents, illness, loss of property incurred by the participants during the training period.

13. Liaison Address: Attn: Mr. Pan & Ms. Shen Xuequn
Hangzhou Regional Center (Asia-Pacific) for Small Hydro Power
Hangzhou, P.R. China, 310012;
Phone: 0086 571 88086586;
Fax:88062934
E-Mail:dqpan@hrcshp.org
Web Site: www.hrcshp.org

■

Application Form for 2004 TCDC Training Course on SHP Equipment

(Please type or print)

1. Family Name:

First Name: **Photo**

2. Date of Birth **3. Country of Birth**

4. Present Nationality

5. Sex
[ ] Male [ ] Female

6. Marital Status
[ ] Single [ ] Married

7. Profession

8. Present Mailing Address

Telephone (City Code)

Fax

9. Permanent Address

Telephone

Fax

Email

10. Person to be contacted in Case of Emergency

Name
Phone
Address

11. Mother Tongue ______________

Other Languages	Read	Write	Speak	Understand
________________	_______	______	_______	____________
________________	_______	______	_______	____________
________________	_______	______	_______	____________

"fl" for fluent, "g" for good, "fa" for fair, "p" for poor

12. University or technical education of over 6 months' duration

From-To	Institutions/city/country	Main study field	Degree
____________	_________________________	____________________	______________
____________	_________________________	____________________	______________
____________	_________________________	____________________	______________

13. Your Present Work (including organization name & your functional title):

14. Medical History (Mention any Significant Physical Illness)

15. Purpose of Your Application:

16. I certify that the statement made in answer to the foregoing questions are true and correct to the best of my knowledge. I realise that any misrepresentation or omission on this form renders my application to be reconsidered or even to immediate dismissal.

Date: ____________ **Signature:** ____________

day/month/year

17. Comments by Recommending Institution or Person:

18. Comments by Chinese Embassy

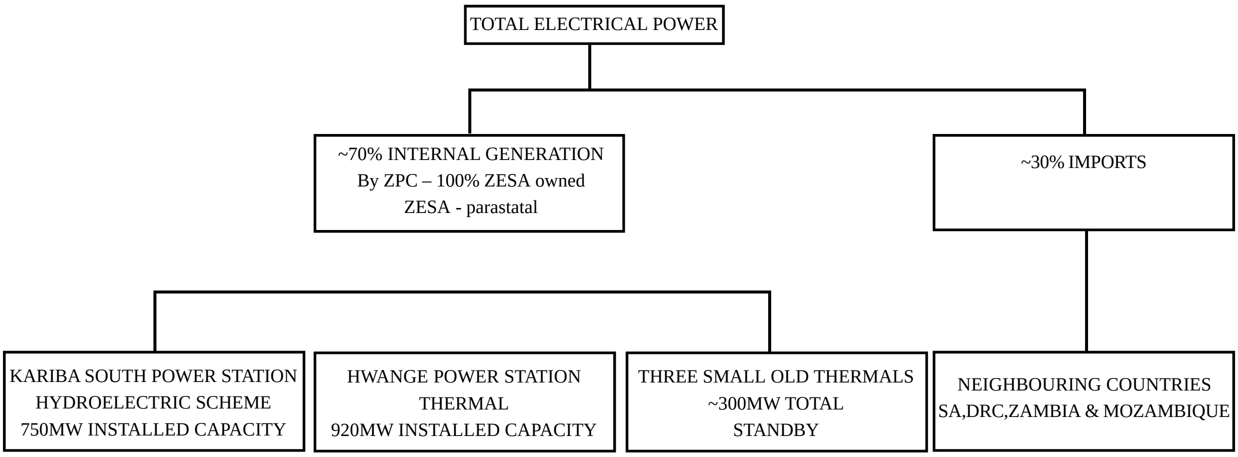
Seal: ____________

Date: ____________

Country Paper on Small Hydro Power
ZIMBABWE

BY WELLINGTON MAPHOSA
PROJECTS ENGINEER,ZIMBABWE POWER COMPANY

1 OVERALL POWER PICTURE IN ZIMBABWE – AS AT OCTOBER 2003



On Going Power Sector Reform Programme Would Enable Injection of Private Sector Capital in Power Production

2 SMALL HYDRO POWER POTENTIAL

The development of small hydropower in Zimbabwe to date is minimal. There is however a lot of potential from perennial rivers in the Eastern Highlands and from inland irrigation dams as shown in Table 1. The total potential for small hydro power is over 60MW.

Increased local power production from small hydroelectric power projects would contribute to reduction of Zimbabwe's dependency on power imports.The electricity sector is currently closed as shown by the regulatory for small hydropower development in Annexure 1. The electricity sector is however undergoing reform and this would enable injection of private sector capital in power generation – joint ventures and /or independent power producers.

3 SMALL HYDRO POWER FEASIBILITY STUDIES

Feasibility studies have been carried out on three selected sites with a total of 30-35 MW. Two of the sites have been studied to implementation stage.Feasibility studies are yet to be done on the majority of potential sites indentified in Table 1. Feasibility studies were done by Norconsult International of Norway whilst environmental issues were investigated by Interconsult Zimbabwe (Pvt) Ltd. Calculation of civil works was done by Stuart Scott Zimbabwe (Pvt) Ltd.

The scope of the feasibility studies covered the following main aspects of each of the projects: background work, field work and comceptual layout and cost estimates.

3.1 Background work

Collect, study and review basic data, reports, maps and other material relevant to the study areas.

3.2 Field work

i) Assess the hydrology by estimating minimum flow, means, annual discharge and maximum design flood on the basis of existing hydrological and metereological records and by simple local observations and interviews.

ii) Collect and analyse existing climatic records for the project areas. Recommend on further hydrological investigations to be performed if necessary.

ZIMBABWE POWER COMPANY RENEWABLE ENERGY PROJECTS

MINI-HYDROELECTRIC GENERATION PROJECTS

DAMS

TABLE 1

NAME	MUKOSI	GWAI/SHANGANI	OSBORNE	MAZVIKADEI	SEBAKWE	DARWENDALE	ZVOZVE	ZIMINYA
District/Province	Chivi/ Masvingo	Tsholotsho/ Matabeleland North	Makoni/ Manicaland	Lomagundi/ Mashonaland West	Kwekwe/ Midlands	Zvimba/ Mashonaland West	Beitbridge/ Matebeleland S.	Nkai/ Matebeleland N.
Altitude	955m	1209m	1600m	1420m	1344m	1452m	650m	1286m
Max & Min Temp.	30.7℃&15.3℃	29.8℃&12.6℃	25.1℃&13.4℃	28.4℃&13.2℃	28.3℃&12.4℃	26.1℃&12.2℃	30.1℃&16.2℃	26.0℃&11.5℃
Live Capacity	495 x 10^6m^3	634.27 x 10^6m^3	400.9 x 10^6m^3	345.00 x 10^6m^3	146.9 x 10^6m^6	492.13 x 10^6m^3	112.0 x 10^6m^3	94 x 10^6m^3
Yield at 10% risk	364 x 10^6m^2	209.15 x 10^6m^3	167.0 x 10^6m^3	99.7 x 10^6m^3	68.2 x 10^6m^3	107.20 x 10^6m^3	44.25 x 10^6m^2	27.694 x 10^6m^3
Mean annual discharge	$11.54m^3s^{-1}$	6.6 m^3s^{-1}	5.3 m^3s^{-1}	3.2 m^3s^{-1}	2.2 m^3s^{-1}	3.4 m^3s^{-1}	1.5 m^3s^{-1}	0.88 m^3s^{-1}
Full supply level	701m	906.00m	1090.7m	1158m	1260.4m		538m	
Outlet level	636m	847.00m	1044.0m	1119m	1240m			1.1m
Riverbed level	620m	800.00m	1030.0m	1100m	1221.0m		518.5m	
Gross head available	86m	106m	60.7m	58m	39.4m	23m	19.5m	31.4m
Discharge outlets	3 x 200mm steel	(200mm,2400&3 x 1200mm Conc.)	3 x 900mm (Conc)	1.5m Conc.(260) and 1.1m steel (128m)	1 x 1400mm &2x1000mm(all conc.)	2 x 3m Conctrete	2 x 1500mm steel	
River Gradient	1:100	1:50	1:1000	1:500	1:500	1:500	1:1500	1:500
Length of penstock	1500m	100m	150m	260m	300m	250m	150m	150m
Optimum size of Penstock	2.5m double concrete	2.5m double concrete	2.0m	2.0m	1.5m	2.0m	1.7m	1.1m

Table1(Contd.)

NAME	MUKOSI	GWAL/SHANGANI	OSBORNE	MAZVIKADEI	SEBAKWE	DARWENDALE	ZVOZVE	ZIMINYA
Working Head	81m	104.5m	58.4m	57.4m	39.0m		18.6m	30.8m
Distance to load centre	12km	15km	2km	7km	5km	25km	5km	6km
Available grid	33kV and 132kV 20 km away	33kV 15km away	11kV	11kV	33kV	11kV	33kV	None
Population Servitude	1200 home steads	450 home steads	1650 home steads	Located in commercial farming area	Located in commercial farms	Located in commercial farming area	200 home steads	850 home steads
Power available	9130kW	6890kW	3030kW	1750kW	840kW	740kW	270kW	260kW
No. of units	10	20	5	5	3	3by 350kW	3 by 100kW	3 by 100kW
Turbine setting	Z_{max}=-1.44m K_n=0.16 C_c=0.13	Z_{max}=-2.3 K_n=0.153 C_c=0.11	Z_{max}=1.6m K_n=0.202 C_c=0.185	Z_{max}=0.0m K_n=0.154 C_c=0.112	Z_{max}=0.0m K_n=0.138 C_c=0.09	Z_{max}=0.0m K_n=0.129 C_c=0.08	Z_{max}=0.0m K_n=0.09 C_c=0.034	Z_{max}=0.0m K_n=0.076 C_c=0.03
Geology and locality	Granitic bolder	High grade metamorphic & Karoo resistant quartzize	Solid Granite	Granitic site with flat bedrock	Granitic bolders	Granite outcrops	Karoo aged basalt & pyrodastic rock	Karoo Resistant Quartzize
Environmental Impact	Clearance of transmission lines and sub-station	Minimum - clearance of distrib lines and pick up weir	Minimum (clearance of distrib. Lines.	None-distrib. Network is in place	None-distrib. Network in place and no excavation of power house	None	Minimum- (clearance of distrib. Routes and substation	Clearance of Distrib. Routes and sub station.

PERENNIAL RIVERS

Table 1 (Contd)

Site	Duru	Jora	Gairezi	Gairezi falls	Chipita	Mudzoro	Tandai	Nyangombe	Nyabamba	Odzani	Tanganda	Kute
Site Coordinates	S18°35' S32°42'	E18°35' E32°42'	E18°35' E32°42'		E18°17.09' E32°39.89'	E18°17.09' E32°39.89'	E18°17.09' E32°39.89'	S18°17' E32°40.89'	S18°1.30' E32°40'	S18°1.46' E32°45'	S19°34' E34°47'	S18°12.30' E32°53.64'
Altitude	1403m	1280m	1489m	1880m	505m	1565m	1195m	1568m	518m	1489m	984m	1514m
Available head	240m	30m &70m	26m	84.3m	34m	150m	88m	25m	18m	51m	8m	134m
Min. discharge	1.3m^3s^{-1}	3.2 m^3s^{-1}	8.5 m^3s^{-1}	1.6 m^3s^{-1}	4.4 m^3s^{-1}	0.8 m^3s^{-1}	1.2 m^3s^{-1}	4.0 m^3s^{-1}	3.0 m^3s^{-1}	0.73 m^3s^{-1}	2.1 m^3s^{-1}	0.1 m^3s^{-1}
Length of penstocks	260m	150m	30m	150m	300m	200m	350m	200m	20m	1500m	450m	150m
Optimum penstocks	1.0m	1.5m	2.5m	1.2m	2.0m	0.8m	1.0m	1.5m	1.5m	1.5m	2.0m	0.5m
Available grid	33kV 5km away	None	None	None	33kV, 500m	33kV, 500m	33kV 5km away	33kV, 6km away	33kV, 500m	33kV, 500m at water works	5km away	None
Population servitude	800hs, 2shcs, 3ts & 2cins	1200 home steads	1200 home steads	350 home steads	700 home steads	200 home steads and *Arda	Cashel Valley & Forestry Comm. Estate	Estates and Saw mills	At tea estate	Water works and estate	1600 home steads	200 home steads
Geology of locality	Bold granite	Quartzite	Bold Granite	Solid flat bed granite	Bold granite	Bold granite	Metamorphic quartize	Metamorphic quartize	Bold granite	Bold Granite	Old metamorphic	Bold granite
Power Available Min. Average Max.	3032 6064 18192	3014 6028 18084	2036 4072 12216	1300	1413 2826 8476	1161 2322 6966	1012 2024 6072	860 1850 5830	480 1012 2550	370 644 1760	160 345 960	131 265 750
Ave Flow	2.59	6.41	17.01	3.3	8.83	1.63	2.41	8.1	18.02	1.47	1.43	0.21
Max Flow	7.82	19.21	52.78	9.72	26.42	4.79	7.22	24.08	6.01	4.38	12.8	0.87

*Agricultural & Rural Development Authority

iii) Assess the river gradient/available head, to determine the head available and the sustainability of power generation. Decide on the most suitable locations for power development.

iv) Estimate data on erosion and sediment transport.

v) Undertake longitudinal profiling of rivers within the project areas and cross sectional leveling of potential sites.

vi) Collect and review existing information on geological conditions in the project areas.

vii) Carry out preliminary survey of geology and soil and determine further surveys and tests to be done during the implementation stage.

viii) Collect and evaluate existing data on the possible seismic risks in the project areas.

ix) Analyse and determine access routes to the project sites and means of transport and costs, as well as load and dimension limitations for transport of equipment.

x) Investigate available local services capable of undertaking transport contracts and civil works for the power plants.

xi) Collect data and assess the local grid and possible impact and need for investment due to the project.

xii) Perform initial environmental impact screening in collaboration with the authorities and according to relevant regulations.

3.3 Conceptual layout and cost estimates

Work out conceptual layout of the power plant and cost estimates to a level of priority list.

4 IDENTIFIED SITES FOR INITIAL SHP DEVELOPMENT

Three sites on perennial rivers in the Eastern Highlands have been identified for initial small hydro power development by Zimbabwe Power Company. These are Tsanga, Duru and Gairezi. Two of the sites, Tsanga and Duru, have been studied to implementation stage. A detailed feasibility study is yet to be done for the Gairezi scheme.

All three schemes are run-off-river projects without reservoirs for seasonal storage. The feasibility study for interconnection of the proposed small hydros was done the electricity utility ZESA. The new power plants would be connected to the national grid. All power plants are designed for a daily peaking mode of operation in the low flow season.

Some hydrological data was found by interpolation or extrapolation of data from nearby sites because of absence of gauging stations on some of the identified sites.

A local consulting engineering company has produced an environmental and socio-economic impact assessment study for Duru and Tsanga. The EIA has revealed that there will be no negative biophysical impact, and no resettlement of population will be needed. No negative socio-economic impacts are expected. The design of power plant will not disturb existing irrigation schemes and other uses of water.

4.1 Key results of feasibility studies

Scheme	Installation (MW)	Annual Production (GWh)	Installation Cost (Million USD)	Unit Cost of Generation (Usc/kWh)
Tsanga	3.0-3.3	8.8	2.1	2.3
Duru	2.0-2.3	6.0	1.8	2.8
Gairezi	25-30	70	25	3.3

4.2 Project scope

It is recommended to implement the Duru and Tsanga schemes under the same contract as the investment is relatively small, the physical distance between them is not too long and particularly the management, design and supervision may be reduced significantly by such an arrangement.

4.2.1 Tsanga scheme

The scheme comprises a low concrete / masonry intake dam, which creates an intake pond with a live storage volume of about 50,000 m^3, a 480m long headrace canal, intake, a 320m long penstock with diameter 1.0m on concrete foundations constructed on exposed rock and a surface powerhouse with a short tailrace leading back to the Tsanga River. Two horizontal Francis units are proposed. Construction period is estimated at 1.5 years.

4.2.2 Duru scheme

The scheme comprises a low concrete / masonry intake dam, which creates an intake pond with a live storage volume of about 7 000 m^3, a 1450m long penstock with diameter 450 / 550 mm on concrete foundations and for the major part of the penstock installed in a trench which is to be backfilled and with a powerhouse with a short tailrace canal leading back to

Duru River. One pelton unit is proposed. Construction period is estimated at 1.5 years.

4.2.3 Gairezi

The scheme comprises a concrete / masonry intake weir, an intake pond with a live storage volume of about 200,000 m^3, intake, a 4.5km long headrace tunnel with a net area of 8 m^2. A possible additional catchment area of one tributary to Gairezi is identified as suitable to be implemented in the scheme by a drilled shaft to the tunnel. This may also serve as a surge shaft for the headrace tunnel. A steel lining of the last 300m of the tunnel to the surface powerhouse is included in the present plan. Two 15 MW Francis units are proposed. Construction period is estimated at 2.5 years.

5 FINANCING PROPOSALS FOR IDENTIFIED SITES

There are various financing proposals for the identified sites for initial development at Tsanga and Duru.

One propsal has a debt:equity ratio of 70:30. ZPC would invest 30% of the required equity. A private strategic investor would take up 51% and become the majority shareholder. The stragegic partner will have the technical experience and management capability in developing and operating power generation plants of similar size. 19% of the shareholding will be offered to other local and international investors. This group may comprise institutional investors. The equity contribution by ZPC and other local investors are expected to meet the local costs while that from foreign investors will be used to source power generating equpment.

A second proposal is to set up a company that would finane the development of mini-hydroelectric schemes in the Eastern Highlands. ZPC would transfer all the work done to date and the mandate on all identified potential to this entity.

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ANNEXURE 1

REGULATORY STRUCTURE FOR SHP DEVELOPMENT

GOVERNMENT OF ZIMBABWE

• Institutional framework
- Co-ordination and consents
- Policy framework
- Creation of conducive environment
- Facilitation of implementation of small scale hydros

ZIMBABWE ELECTRICITY SUPPLY AUTHORITY ZESA
100% GOVERNMENT OWNED

• Beneficiary

ZIMBABWE POWER COMPANY - ZPC
100% ZESA SUBSIDIARY OWNED

• Implementation of selected viable projects

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The MWR's Key Scientific and Technical Project — "Development on Medium and Small-sized Water Pumped Storage Plant" Passed Appraisal

A MWR's key scientific and technical project called "Development on Medium and Small-sized Water Pumped Storage Plant", which was completed by National Research Institute for Rural Electrification, passed an appraisal organized by the Department of International Cooperation, Science and Technology, MWR. After hearing the achievement report presented by the working group; and evaluating the research documentation and information concerned, all the experts drew a conclusion that this is the first scientific research project in China specialized in the development of medium and small-sized pumped storage plant with relatively systematic and comprehensive illustrations. Its research components partially filled in the gap for the development of medium and small-sized pumped storage power plant in China and played a positive role in promoting the further exploitation of this kind. The general development and research achievement reached the top level compared with other domestic research projects of same kind then. Furthermore, the research on the semi-underground powerhouse and the mathematic model of whole characteristic curve for the reversible unit became internationally advanced. With significant social and economic benefits, there's a prosperous prospect for the application of this research achievement.

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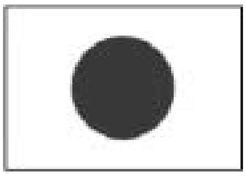

Report submitted by:
Electricity Infrastructure Division,
Ministry of Economy, Trade and Industry, Japan

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4 HYDROPOWER DEVELOPMENT

4.1 History of hydropower

4.1.1 Beginning of the development of hydropower

In Japan, 1860 to 1890 was the period of rapid development of the modern State and the establishment of centralized authority. After constructing the framework for the modern State, the Government pursued a policy of economic modernization. New industries were stimulated by establishing Government-managed model factories and introducing subsidy systems, or by introducing measures to increase industrial production, including selling Government factories to promote private enterprise, and implementing policies to protect industries established to satisfy military and civilian demand.

During this period, which was Japan's first industrial revolution, factories replaced human strength and water-wheels by steam-powered machinery as the power sources, and electricity appeared as a new form of energy. Sources of power for industrial use for 2,000 factories throughout Japan in 1879 were water power 40%, human power 44%, steam 4%, and others 12%. But by1897, electricity came into widespread use and a rapidly increasing demand for electric lighting was accompanied by a gradual growth in demand for electricity as a power source. At first, all the power for electric lights was generated by steam power produced by burning coal, but hydropower development began around the same time. Hydropower was first developed by the spinning (1887) and mining (1889) industries to power their own factories.

The production of hydropower by a power utility company started in Kyoto in 1891. The Government of Kyoto Prefecture planned the Lake Biwa drainage canal project to speed up the modernization of the city, which, after thriving for 1,000 years, had declined following the transfer of the Court to Tokyo in 1869. Thanks to this project, the canal carried water from Lake Biwa to Kyoto, river boats transported cargo between Lake Biwa, Kyoto, and Osaka,and the water also turned water-wheels to produce power. It was also used to protect the temples and shrines of Kyoto from fire, to treat wastewater discharged from the city, and as irrigation waterfor agriculture.

Work on the 11 km-long drainage canal began in 1885 and was completed in 1890, and water flowed continuously from Lake Biwa to Kyoto for the next 100 years. In 1888, as construction of the drainage canal was progressing rapidly, a hydropower project was announced and a survey team was sent to America.

In 1889, a hydro project was approved. Work on the Keage power station began in 1890 and it began generating power in November 1891. The power generation equipment installed at the station at that time included two water turbines with an output of 120 HP and two generators with a capacity of 80 kW.

4.1.2 Period of expansion in hydropower development

From 1900 to 1915, the extremely rapid growth in the electric power market spurred a remarkable growth in the electric power industry. During this period, the method of producing electricity was radically transformed from thermal to hydro, and hydro to thermal. Hydropower surpassed thermal power in 1911 and continued to dominate production for almost half a century, until the 1960s.

In 1945, Japan's surrender ended the Second World War. Electric power demand immediately after the end of the war temporarily exceeded supply, as the complete disappearance of military demand halved electric power consumption. But in 1946, shortages and sharp increases in the prices of coal, oil, and gas spurred the widespread use of electric heaters and rapidly increased demand for electric power to heat ordinary homes and to rebuild industry. The 19.5 TWh of power generated in 1945 rose to 29.4 TW by 1947. In 1948, the Five Year Plan for Economic Recovery was announced, setting out the position and goals of electric power production for the first time. To restore the economy of Japan, with its few natural resources, it was essential to develop abundant domestic hydropower to achieve the goal of making Japan a trading country. This was the perfect time for hydropower development.

4.1.3 The golden age of hydropower development

In 1952, the Second Electric Power Development Coordination Commission adopted the Five Year Plan for Electric Power Development which included nine power utilities, the Electric Power Development Co., Ltd. (J-Power), public electric power utilities, and so on. The goal of the plan was to produce 4,000 MW by the end of 1956, and it prioritized the construction of reservoir type or regulating pond-type powerplants to utilize the hydropower resources effectively. During this period, full-scale electric power development began, and hydropower development entered its golden age. Of the top-ten largescale reservoir and regulating pond type electric powerplants ranked by output, six (Tagokura, Okutadami, Sakuma, Kurobe River No. 4, Miboto, and Hitotsuse) began operating between 1956 and 1963.

Although the postwar economy developed remarkably and electric power was developed aggressively, electric power demand continued to increase sharply every year. To satisfy this demand, electric power utilities were compelled to guarantee their supply capacity by undertaking large-scale electric power development. The emergence of limitations on the locations for hydropower development, and a fall in world prices for oil, shifted priority to the development of high-efficiency, high-capacity thermal plants. Power generation shifted back to thermal first, followed by hydro, and in 1962, the ratio of hydro to thermal power shifted back to 45:55. Then, in 1966, nuclear power development began.

Although thermal power production continued to advance rapidly from then on, it has one shortcoming. Because of its character-istics, a thermal power system is an uneconomical source of power to meet peak demand, and cannot respond promptly to abrupt load fluctuations. The solution was to use thermal power to provide the base supply and hydropower to meet peak power demand. The utilities were therefore required to develop large-scale pumped-storage plants to support the thermal plants which were successively being constructed. Pumped-storage stations produced only 58 MW (0.3% of total power production) in 1960, but a massive production capacity of 3,390 MW (5.8% of the total power production) was achieved by 1970.

4.1.4 Role of hydro in the diversification of electric power sources

This period of large-scale electric power development was accompanied by increasingly severe pollution problems and it became difficult to obtain land because of compensation problems and rising land prices. The number of locations where power stations could not be built in the face of local opposition began to increase in 1968. In 1974, it was possible to secure only 31% of the candidate plant locations set by the Electric Power Development Coordination Commission for that year, and it has become increasingly difficult to achieve the plans. The socalled "Three Electric Power Laws" was therefore enacted, namely the Law for the Improvement of Regions Surrounding Electric Power Generation Facilities, Law for the Promotion of Electric Power Development, and Law for Special Accounting Measures to Promote Electric Power Development.

The effect on the electric power industry of the policy to reduce the use of oil following the two oil crisis in 1973 and 1979 was a second good opportunity for the development of hydropower, based on the renewed awareness of the importance of hydraulic power as a purely domestic energy source to reduce dependence on oil, and to diversify sources of electric power. Subsidies were introduced to promote the development of hydropower under the revision ofthe Three Electric Power Laws.

4.1.5 Performance of environmental impact surveys

To resolve the pollution and environmental problems which emerged throughout Japan in the 1960s, the Basic Law for Environmental Pollution Control was enacted in 1967, but pollution continued to increase. In 1972, the Government won cabinet approval for "Environmental Conservation Measures for Public Works Projects," and the Third National Integrated Development Plan stipulated that environmental impact assessments must be carried out.

Environmental surveys of power station locations were done by the Ministry of International Trade and Industry from 1973, but in 1977, a ministerial decision was taken to "strengthen environmental impact assessments and environmental surveys at the locations of power stations". In 1979, the Agency of Natural Resources and Energy responded by announcing the "Guideline for Environmental Impact Assessments and Environmental Surveys at Locations of Power Stations, " as a specific implementation guideline. An Environmental Impact Assessment Statement for the location of a hydropower station includes five items:

• outline of the plan of the power station;

• present state of the environment;

• measures to be introduced to conserve the environment, and a prediction and assessment of the environmental impact;

• other measures to be implemented to conserve the environment;

and,

• an overall assessment.

It is stipulated that this statement must contain: a detailed report of the plan, based on the need for the power station; estimates regarding the protection of nature and changes in noise, vibration and water quality levels during construction and after the start of operation; measures to prevent these changes; and, an assessment of their impact.

4.2 Present state of hydropower development

4.2.1 Present stage of hydropower plants

After the oils shocks of the 1970s, the extensive development of hydropower, a domestic energy source, resumed, and the share of thermal energy and nuclear power in all the power generation systems increased. This was accompanied by an aggressive development of large-scale pumped storage plants to adjust the supply during peak periods. As a result, the pumped storage share of all the hydropower capacity has increased steadily.

The total capacity of hydropower plants providing power to the general public at the end of 2000 was 44.78 GW, with conventional hydropower producing 20.08 GW, and pumped storage (including both combined and stand alone plants) producing 24.71 GW; the share of pumped storage plants of all the hydro plants was 55.2%.

At the end of 2000, 1583 hydro plants were in operation, or 1,712 including 129 nonutility generation plants. These include 501 conventional hydro plants (plants with a capacity of 10 MW or more, with a total output of 17.31 GW) and 43 pumped storage plants (combined and standalone pumped storage, with a total capacity of 24.71 GW). The total capacity of hydro plants under construction or at the planning stage at the end of 2000 was 13.27 GW, with 390 MW of this from conventional hydropower plants and the remaining 12.88 GW from pumped storage plants (combined and stand-alone). Because conventional hydro plants are less economical and require more work in relation to their scale compared with other types of plants, in recent years an annual average of between 70 and 80 MW only has been developed; this is a far slower pace of development than in the past. The pumped storage plants now under construction include large schemes such as the Kanagawa powerplant (stand-alone p-s, 2.7 GW), Kaore (stand-alone p-s, 1.3 GW). and Omarugawa (stand-alone p-s, 1.2 GW).

Table 4.2.1 – Japan's hydropower potential

Category		Number of locations	Max. output (MW)	Annual production capacity (MWh)
Developed (1)	Conventional	1,819	21,777	91,453,469
	Combined pumped storage	20	5,727	2,633,631
Under construction (2)	Conventional	48 (4) -9	537 -49	1,277,237 -287,502
	Combined pumped storage	1	400	255,600
Unexploited	Conventional	2,715 -258	12,114 -1,003	45,823,922 -6,878,909
	Combined pumped storage	20 -13	7,956 -124	1,793,400 -711,912
Total	Conventional	4,578 -267	33,376	131,388,217
	Combined pumped storage	41 -13	13,959	3,970,719
	Total			135,358,936

1. "Developed" includes plants in operation at the end of March 2001, and is the total for all power plants operat-ed by utility companies and all non-utility power plants with maximum output of 100 kW or more.

2. "Under construction" includes plants planned by December 2000, and is the total for all power plants whose request for approval for the construction plan was approved or whose advance notification of the work plan had been accepted by the end of March 2001.

3. Minus signs denote the extent to which the status will shortly change, eg, as new projects are completed.

4.2.2 Japan's hydropower potential

According to a survey of hydropower potential at the end of March 2001 conducted by the Ministry of Economy, Trade and Industry,there were 2,715 undeveloped conventional hydropower locations in Japan. Developing these sites would produce a total of about 12.11 GW, and their average capacity would be approximately 4,460 kW (Table 4.2.1).

As the scale of such sites has decreased, it is now more difficult to obtain the benefits of scale, and the unit cost of development has risen. Furthermore, growing concern in recent years over envi-ronmental conservation among those living near rivers has made it more difficult to secure locations for power stations.

4.3 Future of hydropower development

4.3.1 Hydro development promotion policies

The Ministry of Economy, Trade and Industry has established the "Committee to Enact a Hydropower Plan for the New Century" as a private discussion group reporting to the Director of the Public Works Department, to study policies to promote the development and introduction of future hydropower plants based on hydropower trends. It presented a report in 1993, which recommended the following four major policies.

(1) Strengthen efforts by electric power utilities and improve the economic benefits of hydropower

• Take steps to develop plants at locations 30 to 40% higher than in the past.

• Further reduce costs by developing and introducing new technologies and increasing the flexibility of development organizations and systems.

• Study more complete and effective government support policies to encourage the development and introduction of technologies.

(2) Strengthen hydropower promotion systems

• Establish public (regional governmentoperated) power utilities and strengthen the efforts of electric power wholesalers by using human resources more extensively.

• Strengthen the efforts of electric power utility companies through personnel resources at regional branch offices and so on, and the use of public corporations and companies involved in hydropower development.

(3) Encourage understanding among the residents of development regions and the general public

• Conduct more aggressive and effective publicity campaigns by the Government and electric power utilities.

• Provide information to educators and use PR centres, power stations, and so on, as educational facilities.

• Study ways in which utilities can contribute to regional development by building powerplants in harmony with the surroundings,and ways of expanding and strengthening Government support policies.

• Strengthen links with ministries and agencies to smooth procedures for developing hydropower.

(4) Greater encouragement for international cooperation

• Strive to form an international consensus and domestic public opinion concerning cooperation in the development of hydropower in developing countries.

• Compile data concerning hydropower potential and plan integrated development programmes by river system in developing countries.

• Propose small-scale spot development to achieve internationally applicable development, and bring electricity to villages.

• Provide an international cooperation infrastructure in Japan to encourage electric power utilities to improve their systems, to provide manuals, and to develop technologies which meet the needs of other countries.

To promote cooperation in hydropower development as a national policy, tax measures are being prepared to:

• reduce the cost of technical development:

• promote environmental conservation policies and regional policies;

- subsidize construction costs;
- create more developers;
- rationalize development methods;
- contribute funds to regional municipal governments to mitigate the impact of projects;
- provide low-cost financing by the Development Bank of Japan; and,
- promote development of small and medium-scale hydropower.

4.3.2 Technology development related to hydro

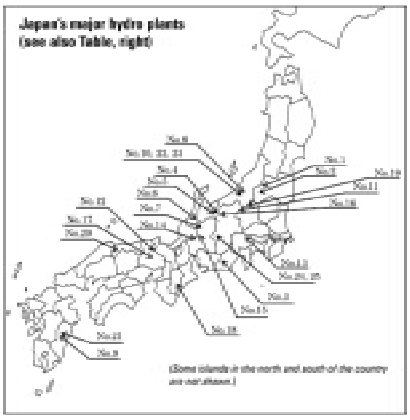
In future, hydropower development will be characterized by smaller scale projects (average size 4600 kW) and more locations (approximately 2700). To encourage the development of small and medium scale hydro plants that do not offer good economies of scale, it is essential to develop new technologies to reduce construction costs and increase the economic efficiency of the plants.The Government began a design survey of small and medium scale standardized model hydropower plants in 1981, and over the next 21 years up to 2001, carried out a wide range of surveys and studies, rationalizing electric power generation systems, developing new materials and construction methods, and analysing and evaluating tests to corroborate the design and reliability of trial plants. It is also developing pumped sea-water storage plants which will expand the range of potential locations for hydropower production; this is the only large-scale electric power storage technology now in practical use.

(1) Survey of the design of small- and medium-scale standardized plants

Of the various technologies which can reduce the cost of construction of small and medium-scale hydropower plants, research and development will be conducted on the following, which are considered to have the greatest potential. Verification trials of these new technologies will also be carried out at actual development sites.

- development of integrated hydro turbine generators;
- development of new light load runners for medium and high heads;
- development of technology such as FRPM pipe to replace penstocks;
- rationalization of civil engineering systems, for example by eliminating spillways;
- development of unmanned power stations;
- rationalization of tunnel construction by NATM or sprayed concrete;
- rationalization of tunnels constructed by the TBM method;
- the use of bear-trap dams made of rubberized material;
- rationalization of low head hydro plant dam foundations;
- development of technology related to underground construction;
- development of technology related to ultra low head hydro systems;
- development of technology related to integrated hydropower systems;
- development of technology related to penstocks in deep bedrock;
- improvement in the efficiency of hydropower production;
- automatic construction of penstocks;
- boring very small diameter tunnels;
- development of distributed small-scale hydropower plants; and,
- exploring possibilities to import materials, equipment and new technologies.

Regarding distributed small scale modular hydro plants, as part of the measures to encourage the development of unused hydro resources, cases of small hydro development in remote areas closely linked to their surroundings, both inside and outside Japan,have been studied, and standards have been developed for plants which can be easily planned, designed, executed, operated, and maintained. This technology will be used to expand and to promote hydropower development in developing countries, and to contribute to international cooperation.



(2) Seawater pumped-storage development

Pumped-storage is essential for the efficient and stable operation of the nuclear and thermal plants in Japan. As the country is surrounded by the sea and has many good locations for pumped seawater storage plants, surveys are ongoing to identify the many candidate locations for such plants. However, specific plans have not been completed, because the feasibility of a total electric power system capable of overcoming the technical and environmental problems of using seawater has not been demonstrated. Nevertheless, following a basic survey carried out between 1981 and 1986 on the feasibility of seawater pumped-storage, the construction of a pilot plant (30 MW) in northern Okinawa began in 1987, and trial operation of this plant began in March 1999.

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Key to Map: Japan's major hydropower plants

Top ten by installed capacity				
Rank	**Name**	**River**	**Capacity (MW)**	**Map ref.**
Conventional hydropower plants				
1	Tagokura	Agano	380	1
2	Okutadami	Agano	360	2
3	Sakuma	Tenryu	350	3
4	KurobegawaNo.4	Kurobe	335	4
5	Arimine No. 1	Jouganji	265	5
6	Tedorigawa No.1	Tedori	250	6
7	Miboro	Shou	215	7
8	Shin-ojiya	Shinano	206	8
9	Hitotsuse	Hitotsuse	180	9
10	Shinanogawa	Shinano	177	10
Pumped-storage plants				
1	Kannagawa	Shinano/Tone	2820	11
2	Okutataragi	Ichi/Maruyama	1932	12
3	Kazunogawa	Fuji/Sagami	1600	13
4	Okumino	Kiso	1500	14
5	Kaore	Kiso	1300	15
6	Shin-takasegawa	Shinano	1280	16
6	Okawachi	Ichi	1280	17
8	Okuyoshino	Shinguu	1206	18
9	Tamahara	Tone	1200	19
9	Matanogawa	Asahi/Hino	1200	20
9	Omarugawa	Omaru	1200	21
Top ten by electric power production			Production (GWh/yr)	
1	Sakuma	Tenryu	1429.9	3
2	Shinanogawa	Tenryu	1193.2	10
3	Kurobegawa No. 4	Kurobe	926.1	4
4	Shin-ojiya	Shinano	850	8
5	Senju	Shinano	716	22
6	Ojiya	Shinano	672	23
7	Kiso	Kiso	665.2	24
8	Yomikaki	Kiso	613.2	25
9	Okutadami	Agano	612.7	2
10	Tagokura	Agano	594.5	1

A Chinese Magazine "Small Hydropower" by HRC

The Chinese "Small Hydropower", a magazine that National Research Institute for Rural Electrification (NRIRE) and Hangzhou Regional Centre (Asia-Pacific) for Small Hydro Power has edited and published for 116 issues (bimonthly), was allocated with the International Standard Serial Number ISSN 1007-7642, and China Standard Serial Number CN33-1204/TV. It was published in Chinese attached with title of articles in English. Its special features are technical experience of SHP development in China. Information of international SHP activities and important events in the field of SHP have also been widely included.

This magazine carries news, views and articles on all aspects of small hydro power. It is useful to those who are intersted in technical experience of SHP development in China.

"Small Hydropower" is the only professional publication on small hydropower in China, which is issued domestically and abroad. It is widely circled in all corners of China concerning SHP, and getting more and more popular in over 600 rural counties which is primarily hydro-electrified, more than 2,300 counties with hydropower resources, more than 50,000 small-sized hydropower stations, thousands of colleges or universities, research institutes and other administrative authorities on SHP. Advertising is welcome for any equipment manufacturer to target Chinese market on SHP construction, equipment purchasing or other businesses.

■

The main contents of issue No.115 (2004 No 1) read as follow.

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