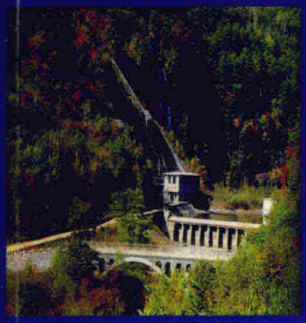

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PREFACE

Over two billion people across the globe still are without access to electricity. Without this source of energy, an immense barrier remains preventing the economic and social development of rural communities. This crisis of energy poverty needs to be tackled by the mutual cooperation of global society. Small hydropower (SHP) as a renewable energy source is proven, clean and environmentally benign. With considerable amount of power potential remaining untapped, SHP can offer a major contribution to the pursuit of electrification for development. SHP usage leads to an increase in employment opportunities, to an improvement in the ecological environment, and to the economic development of rural areas.

China presents an excellent model for sustainable development through SHP, having effectively exploited a substantial proportion of its energy resources. Over 300 million people in China now enjoy the benefits of electrification through SHP. By the end of 2002 in China, 42,221 SHP installations have been built with a total installed capacity of over 28,489 MW. These installations produce annually a total of 94.7 billion kWh of SHP and is growing each year. This is by far the largest capacity installed in any country. Despite the successes, tremendous resources are yet to be exploited, both in China and on a global scale, and improvements in equipment used need to be made.

In order to implement governmental SHP policies, and to create a strategy forum for the duplication of Chinese best practise for SHP development in other developing countries, a centre of excellence named the International Network on Small Hydropower (IN-SHP) was established in Hangzhou, China. Created and sponsored by the Special Unit/TCDC, the UNDP and the Chinese Government, IN-SHP was founded in 1994. IN-SHP is a member-based organization, which provides a forum for information exchange, contacts and support to further the promotion of global SHP development. Its key goals are poverty alleviation, sustainable socio-economic development, increased employment opportunities for local people, improved rural living standards and environmentally friendly development. Within China, IN-SHP's professional team has been effective in implementing governmental policies, such as 'Self-Construction, Self-Management and Self-Consumption'.

The capacity of IN-SHP has evolved dramatically over the last ten years. Signalling a landmark for the development of SHP worldwide, a new headquarters was constructed for IN-SHP in 1998, with funding from the Chinese government. In 1999, with the approval of the State Council of China, IN-SHP was established as China's first ever international organization. In 2000, the legal status of the International Center was approved by the Central Institutions Committee, and the international

secretariat of IN-SHP, entitled the International Center on SHP (IC-SHP), was established under the auspices of UNIDO.

IN-SHP has been widely recognised for its innovative use of 'triangular cooperation' among developing countries, developed countries and international organizations, which has enabled it to promote SHP development across the globe. The character of IN-SHP is embodied in its staff, whose hard work, commitment and enthusiasm have enabled the realisation of IN-SHP's breadth of achievements.

I would like to express my gratitude to Professor V. K. Damodaran, my colleague, for his erudite support and advise in the construction and revision of this new edition; to Mr Okon Ekpenyong, Division Chief of the Technical Cooperation between Developing Countries, for his contributions to its revision. Furthermore, for editing and formatting with great patience and skill, I would like to extend my thanks to Wei Jianghui. Thanks are also due to Huang Yan, Hu Xiaobo, Wang Yansong, Beth Marshall, Wu Mengyuan, Qiou Dale, Wang Xianlai, Yao Dan and Wu Xianhong.

Tong Jiandong

Director, IN-SHP
Hangzhou, China
November 2004

CONTENTS

CHAPTER ONE
A DEVELOPMENT HISTORY

Contributing significantly to sustainable energy policy and development, People's Republic of China is currently operating 42,221 small hydro power stations with a total installed capacity of 28,489 MW, generating 94.7 billion kWh annually (in 2002), supplying adequate electricity to more than 300 million people across 1501 counties (out of a total of 2300) and has its presence in yet other counties. China accounts for 39% of the worldwide SHP capacity built.

1.1 RISE, FALL AND RESURGENCE OF SHP IN CHINA

1. From Humble Beginning to a People's Movement

China is among the very few nations in the world to have harnessed water resources even in the early days of human development. Historical records indicate that towards the end of the Western Han Dynasty, i.e. around 206 BC to 8 AD, hydraulic trip-hammer was used for rice husking in China. But as time passed by, the country's interest in waterpower utilization technologies started dwindling. While some countries started waterpower based electricity generation in the 19th century, it was not until July 1905 that the first hydropower station in China of 500 kW, at Guishan was built along Xindian Brook, a tributary of Danshui River in Taiwan province. From the time of the Revolution in 1911 to the time of the War of Resistance against Japan, which started in 1938, Mainland China had only six SHP stations with a total installed capacity of 2,600 kW.

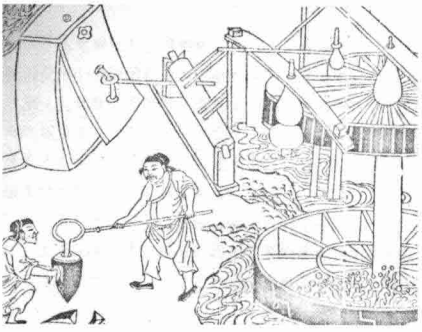
Some of the earliest hydropower stations in China include Shilongba in Yunnan, Dongwo in Sichuan, and Duodi in Tibet. Shilongba is the first hydropower station built in China's mainland, and is located in the suburbs of Kunming. With construction starting in July 1910, it was commissioned in April 1912. Although the local people proposed the project, it was a German construction company that did the work of actual design and construction. Siemens, a well-known German manufacturer supplied the

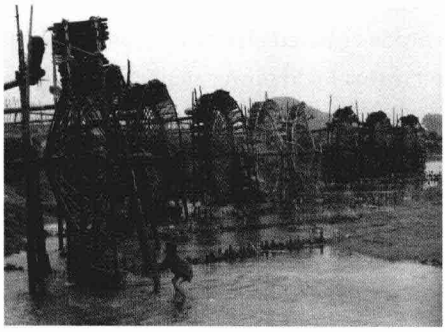
equipment. Initially, the capacity of the station was 2 × 240 kW. But before the birth of the People's Republic of China in 1949, the station was upgraded to 2,920 kW.

The construction of Dongwo station started in 1923. The initial capacity was 175 kVA at the time of its commissioning in 1925. This has the distinction of being the first indigenous SHP station in China. Later, a bigger reservoir was built for a second unit of 300 kW. After a while, each of the two turbines was upgraded to 500 kW. These two turbines are still operating.

Duodi Station, located in the suburb of Lhasa in Tibet, was also constructed in the early times. In 1913, the 13th Dalai Lama sent some persons to England for studying hydropower generation technology. In 1923, two units of 125 hp turbines were purchased from India and in1928, the work on the station was completed and it was commissioned. But due to poor management and low quality of the turbines, the system stopped operating in 1944. By 1949, the total installed capacity of all the hydro stations in the country- large and small - was only 360 MW, i.e., less than 1 Watt per capita and the annual output was 1.2 billion kWh. Globally, China was ranked 20th in terms of installed capacity of hydropower, and 21st in terms of total annual output. At this time, the total number of SHP stations of less than 500 kW was 52 with a total installed capacity of 5,916 kW.

After the birth of new China in 1949, SHP along with agriculture and water supply was vigorously developed. See Fig. 1.1 and Table 1.1. The National Agricultural Development Program formulated in the 50s declared that, "all water resources projects that can be





Harnessing hydropower resources in early days. Even today we can find irrigation system using hydropower

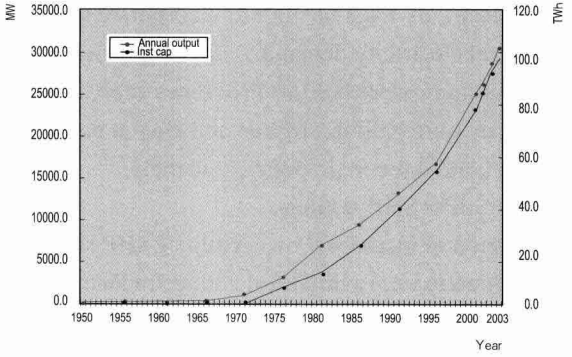


Fig. 1.1 Annual rate of SHP addition in China (1950-2002)

Table 1.1 The rate of SHP development (1950-2002)

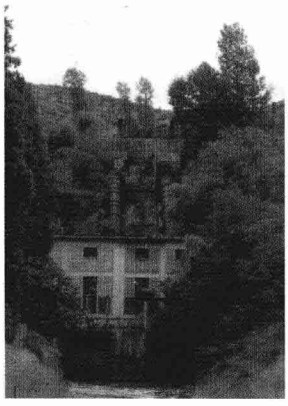
Year	SHP		Ratio:SHP/LHP%	
	Capacity(MW)	Output(10^8kWh)	Capacity	Output
1950	3.7	–	2.2	–
1955	7.0	–	1.4	–
1960	251.4	–	13.0	–
1965	330.0	–	10.9	–
1970	1,019.0	–	16.4	–
1975	3,083.2	6.7	23.0	14.1
1980	6,925.5	12.7	34.1	21.9
1985	9,521.0	24.1	36.0	26.1
1990	13,180.0	39.3	36.6	31.1
1991	13,853.4	37.3	36.6	29.8
1992	14,419.1	44.2	35.4	32.2
1993	15,055.3	47.0	33.8	35.7
1994	15,776.6	50.9	32.2	30.5
1995	16,646.1	55.4	32.7	32.6
1996	19,201.8	62.0	34.5	33.2
1997	20,519.6	68.3	34.4	35.1
1998	22,024.2	71.3	33.8	34.9
1999	23,480.7	72.0	32.2	33.8
2000	24,851.7	80.0	31.3	32.9
2001	26,262.4	87.1	31.7	33.8
2002	28,489.3	94.7	33.7	34.9

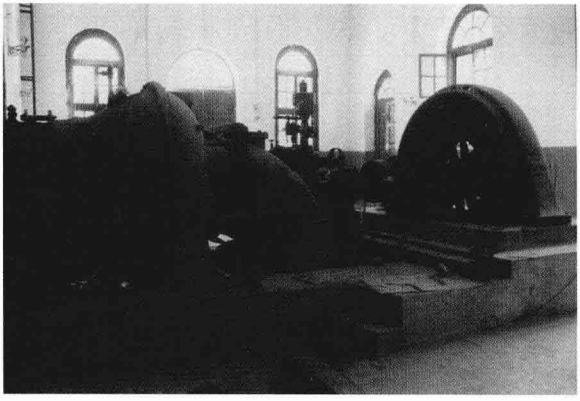
utilized for generating electricity must be built to incorporate medium or SHP stations in order to satisfy the rural electricity demand." In 1956, a series of national training workshops in SHP technology were held in Provinces such as Sichuan, Fujian, etc. Also, national conferences were held in Sichuan and Hunan provinces. The aim of the conferences was to formulate three main policies, namely:

— Give high attention to SHP stations.
— Give high attention to local level ownership of SHP stations.
— Give high attention to improving local cottage industries and productive services in the rural community.

Similarly, two-legged policies were identified, namely:

— Pay equal attention to local and foreign technologies.
— Pay equal attention to electricity generation and mechanical power production.
— Pay equal attention to large, as well as small, mini and micro hydropower stations.
—Pay equal attention to the promotion and use of Small Hydro Power in supplying electricity to rural and isolated communities along with electricity through large grids.





Shilongba, the first hydropower station in mainland China and its equipment

In 1958, cooperatives of local communities for food production were formed. During this time, the State Council directed each province to select five counties and 100 villages for the Rural Electrification Plan to meet the energy needs of the cooperatives of these communities through SHP technologies. All these policies and measures helped to stimulate rural electrification in the whole country.

So, from 1950s onwards, many SHP stations were constructed along with water resources projects. But due to poor industrial base in such rural areas, the capacity of the SHP stations was generally less than 500 kW and the total annual increase of installed capacity was only about 15 MW. By the end of 1960, there were 8,975 SHP stations with a total capacity of 252 MW, leaving the average capacity of the stations at 28 kW. They were thus too small and most of them were operated in isolation. At this time, SHP was called "the bright pearl at night". But, for the rural mountainous areas, it showed the direction of "lighting without oil and milling and agricultural processing without the use of hands". In other words, the 60s saw considerable development in SHP. The central government formulated "Agriculture-based, Industry-directed" national economic policy aimed at encouraging agricultural and industrial activities among its citizens for the development of the national economy. This policy required every citizen to give adequate attention to agriculture and food production.

In 1963, the then Ministry of Water Resources and Electric Power established the Rural Electrification Bureau to focus on issues of high priority to send electricity to rural areas as a key area, such as commercial food supplies, to realize electrical irrigation as a priority task etc, giving equal attention to both large grid and SHP stations in the rural electrification plan. But, it was observed that the primary objective of boosting agricultural production through the connection of SHP stations to the unified grid system was not fully realized, because:

- The main areas that are involved with large scale agricultural activities for commercial food supply had very little or no water resources that can be utilized for generating electricity, while the mountainous areas that have no land for massive agricultural activities were blessed with abundant hydropower potential.
- The fast expanding large grid placed much emphasis on extending it to the suburban and rural areas, resulting in neglect of exploitation and utilization of local SHP resources.

Also, at this time, turbines were only made from low quality materials, such as iron and wood and their average capacities were too small and the stations in most cases were operated in isolation. This resulted into substituting the isolated small hydropower supply with the grid power, even at the prospect of abandoning such SHP stations. Further, during the Cultural Revolution, a number of SHP stations were closed down.

The natural disasters and turbulence also posed a lot of problems for SHP development.

SHP stations were, therefore, operated just to satisfy the basic needs of agricultural production, rural industrial production and household activities. Eventually, the total installed capacity and the rate of development of SHP got diminished. Notwithstanding this, the definition of SHP capacity was increased from 500 kW to 3,000 kW and the average annual addition in installed capacity was 58 MW. During this time, electricity supply from the large grid in the country started becoming erratic and epileptic, with frequent and long power outages. With all these ugly experiences, people started learning their lessons. They realized that:

- Showing just the direction alone is not enough, but there is also need to support and protect the policy of developing SHP stations.
- The rural areas should be made to develop their own SHP stations based on the policy of "Self-Reliance", instead of depending solely on the large grid for supply and distribution.
- In power supply to rural areas, it is much wiser to pay equal attention to both large grid and SHP local grids.

In October 1969, at the instance of the State Council, a national meeting was held in Yongchun County of Fujian Province, where the SHP development in Mainland China pioneered. The aim of the meeting was to summarize the experiences gathered so far from the SHP development through the "Three-Self Policy" and to spread information on the construction of SHP stations. Also, policies were formulated and decisions taken to ensure that the ownership, management and benefits of SHP stations went to those who invested in building the stations. Further, most water resources around the mountainous areas that can be utilized for electricity generation, were exploited with the funds accumulated through the policy of "Electricity Generates Electricity" and the 20% subsidy from the national government, which is limited to 150 RMB/kW. SHP stations for electricity generation were incorporated into most of the water resources projects and connected to local grids, some of which were later connected to the large grid. These approaches have effectively promoted the initiative of the local governments at all levels and had also helped the local people to develop appropriate SHP technologies that fit their local conditions with attractive socio-economic impacts.

This policy helped to develop the initiatives of the county, community and community based cooperatives, in building and generating their own electricity. For example, the central government no longer supplied all the needed equipment and materials for SHP development, but only assisted them partially with some major equipment. The counties thus embarked on indigenous manufacturing of SHP components. The unified system

used in the construction, generation, distribution and management also helped to protect the interests of all stakeholders. Towards the end of 1970s, the local interest in SHP development was renewed greatly, and this led to a change in the definition of SHP capacity from 3 MW to 12 MW by the government. Therefore, the annual average capacity addition increased to 580 MW and in 1979, the newly added capacity touched the level of 1,120 MW.

2. Rural Electrification with a Different Yardstick

In the 80s, most rural electrification programs were implemented through the exploitation of SHP. In most parts of the world, energy crisis of the 80s made renewable energy and particularly SHP, more attractive. In view of the growing worldwide interest in the development of SHP, the Central government formulated a policy based on "economic construction", to stress on the economic development of rural areas and electrification through SHP exploitation. Fortunately, before this time, SHP development in the country had already been well established. Many counties built more local grids of their own. In

RE County Program brought electricity to Inner Mangolia (Longkow SHP Station of 2×3 MW) and to Zhejiang Province Longjingqiao Station (2 × 1 MW)

November 1982, the central government selected 100 counties to experiment the viability of using SHP technologies for the rural electrification program. The demonstration project was to be completed in 1990. The State Council had released a subsidy of 100 billion RMB per annum for the primary rural electrification of trial county program (RE). With the persistent efforts of all concerned, this first phase of RE was successfully completed in 109 counties against 100 targeted, after being tested and approved as conforming to the standards of SHP based RE. It was interesting to see that

48 counties had completed their project even in 1988 — much ahead of the time limit set. These recorded successes helped the State Council to get convinced that rural electrification based on SHP exploitation, is a viable project.

The County Rural Electrification development brought great changes into the SHP development scene in China. The number of SHP stations and the station capacity increased more and more. This changed the definition of SHP by upgrading the capacity from 12 MW to 25 MW. Many counties formed local grids and about 78% of the total SHP installed capacity were connected to each other. Many counties started developing cascade stations. Also Control Centers were established to regulate load within the service areas.

Local Small Hydropower Corporations were established to monitor and regulate the generation, transmission, distribution and the benefits from SHP was continuously increased. This led to a new management system. By 1988, the total installed capacity of SHP in China was 11,790 MW, with annual output reaching 31.6 billion kWh. The transmission lines increased rapidly. High Voltage (HV) transmission lines of 683,600 km and Low Voltage (LV) transmission lines of 1.53 million km with total transformer capacity of 44,413 MVA were constructed. At this time, 717 counties had their electricity supplied mainly from SHP stations. SHP development generated a lot of business activities in the areas of planning, design, construction, operation, maintenance, management and research. This is because SHP technologies have peculiarities, which are different from large-scale hydropower technologies. At this time, 457,000 people were gainfully employed in SHP businesses, and of them, 34,400 were technical personnel. The total valued assets of SHP were 20 billion Yuan. Some of the local grids of the counties were connected together to form Prefecture grids, and some prefecture grids were further connected to the large grids. So, a systematic management mechanism was established at all levels of government (national, provincial, prefecture, county and local).

In the 1990s, the reformation of China and the opening of the country's economy to the world market led to an increase in the rate of SHP development, especially in terms of scale, management techniques, research & development and policies. Specific features of SHP development were established. Also, more stations with higher capacities (medium sized stations) were constructed and the definition of SHP station was amended to cover stations up to 50 MW. Another major development was in the construction of cascade stations in all river basins, unlike in the past, where a single station used to be built in a river basin. Also, there were some improvements in the level of transmission