China and Africa: Small Hydro Power Cooperation

Leon White

The development of Small Hydro Power (SHP) in China has been a success for rural electrification yet to be replicated in the rest of the world. This paper introduces basic technical, financial and policy principles of SHP and examines the factors behind its success in China, before moving on to examine existing Chinese technology transfer and capacity building activities with the Global South, and African states in particular. The paper includes some observations of how a failure to account for development differences between China and the rest of the world often leads to inappropriate measures to develop SHP, and suggests several steps which could be taken to promote similarly rapid SHP development in Africa in the coming decades.

Introduction

The massive development of Small Hydro Power (SHP) in China over the last 50 years has resulted in a reliable and environmentally friendly supply of power to hundreds of millions of rural Chinese spread over half of China's territory. The positive effects are visible in the environment as traditional clear felling for fuel wood has changed to electrical lighting and stoves, and visible socially as time-saving inventions such as e-bikes partially powered by SHP have exploded in popularity. Yet SHP still remains largely undeveloped in large parts of the rest of the world. Africa and Southeast Asia in particular have rich river resources which could provide distributed renewable power to populations without the serious effects on river ecosystems associated with large hydro power.

This report is divided into three parts. The first section includes a brief history of the development of SHP and an overview of the best practices for implementing SHP on a national and regional level according to the experiences of China and other countries with significant SHP deployment. A brief review of the technology and details on the policy environment which best fosters SHP development highlights exactly what it takes to establish a manufacturing base, reliable technical service providers, sources of funding and sustainable management within a country. The second section details the state of SHP today, firstly in China and then for the other major regions of the world, with a focus on Africa and Asia. This section includes examples from specific countries in these regions to describe the successes and pitfalls in developing SHP in different cultures and under different governments. The third section reveals efforts underway by China and the broader international community to promote SHP development in Africa through technology transfer and capacity building, particularly through the work of two organisations in Hangzhou, China: the IC-SHP and the HRC-SHP. It can be seen that while technical support is generally of a very high quality, efforts to adjust poor rural electrification policy and organise sustainable funding remain relatively weak and even counteractive to the stated aims of the organisations. An overview of further reading and a list organisations involved with SHP completes the report.

Contents

Overview of SHP

History

Hydro power started out thousands of years ago through the use of water wheels to operate mills, usually for grain and wood processing. Today, converting this rotational energy to electricity through a hydroelectric generator has a number or advantages, including a greater transmission distance and an ability to power a wide range of tools, residential lighting, and generally improve the quality of life for rural residents. German company Siemens pioneered initial hydro developments in England and the US in the late 19th century, and technical developments since have remained simple and have proven to scale remarkably well. Hydro stations as small as a hundred watts are in productive operation today to power single houses, and the largest dams in the world today are capable of generating tens of gigawatts for the national grid.

Hydropower Classification

Pico	– up to 10kW
Micro	– up to 100 kW
Mini	– up to 2 MW
Small *	– up to 10 MW
Medium	– up to 100 MW
Large	– 100 MW and above

* SHP up to 50 MW in China, 30 MW in USA and 25 MW in Canada

Hydro technology

Hydro power today uses the same basic principle as these historic plants. A dam, weir, waterfall or simple river rapids are used to bring a column of water into a position where it may flow freely downwards. It then passes through a turbine, often using an arrangement of several jets to focus the flow, and the rotational force turns a generator within a fixed magnetic field, resulting in electricity. Two basic factors determine the generation capacity of a hydro power plant: the head and the flow. The head is the height the water falls from before striking the turbine, and the flow is the rate of water passing through the turbine, measured in litres per second, for example. The head is determined by the size of dam or river diversion, which is why large hydro plants require high dams to generate sufficient pressure. The flow is generally determined by the diameter of the pipe (or penstock), and a function of the two, together with one of several possible types of turbines, determines the output of the station in watts.

Hydro plants are classified as either “large” (with output of over 100MW for the national electrical grid) or a range of “small” plants as shown in the info box above, with different accepted generation capacities. SHP is generally defined as anything below 10MW, and this is the definition used in this report. However, for reasons of increasing economies of scale and for administrative purposes, some countries use higher definitions for SHP to give regional utility companies greater leeway in their resource exploitation. This comes at a moderate cost to the environment, and adequate planning is required to avoid the serious environmental effects of some large dams.

A range of different turbines are in use, each offering different efficiencies and suited to different situations. Impulse turbines are the most simple, and generate rotational force by directing a flow of water against the turbine blades. This type may be constructed from simple components or scrap and simply placed in the water flow to result in rotational force. Impulse turbines include Pelton, Turgo and Crossflow wheels. Reaction turbines work on the principle of a change in pressure in the water, and must remain completely submerged during operation. They therefore are usually operated inside a sealed casing,

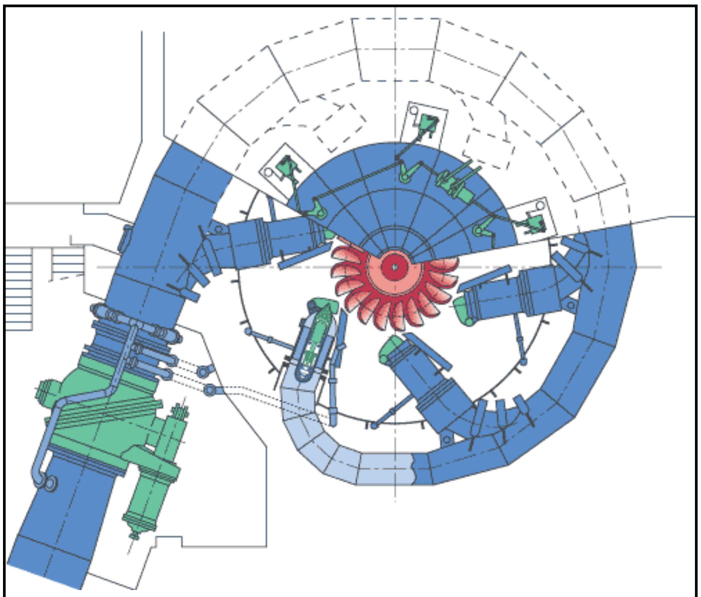

Fig. 1: **Schematic of multi-jet Pelton turbine**
Source: German ProfEC

and may be more fragile and difficult to construct. Reaction turbines include propeller, Kaplan and Francis types, and are particularly well suited to low head sites, making them desirable for SHP situations. Efficiency is also an issue in turbine selection. Impulse turbines maintain relatively high efficiency when the flow rate is reduced due to water shortages (for example in the dry season). Reaction turbines, however, lose efficiency sometimes with as low as 80% of nominal flow, and may cease operation altogether in reduced flow situations. These engineering constraints, as well as issues such as maintenance and clearing obstructions and debris, must be considered when planning the feasibility of a hydro power installation.

Finally, for small grid applications, some form of regulation must be in place to maintain constant current and voltage as the load changes during the day. More complex installations can store excess power using batteries or by pumping water into a reservoir, while simple installations redirect load to ballast, where it is harmlessly converted to heat. This is one of the most difficult technical aspects of small hydro power in particular, and there are many reports of voltage surges during floods destroying electrical equipment, heavy demand reducing voltage so that appliances are unusable or variances in turbine speed causing fluctuations in the frequency of alternating current. New electronic load controllers (ELCs) are available to deal with this problem.

Small Hydro Power

Small Hydro Power (SHP) is a particular type of hydro power characterised by smaller turbines, lower head heights and relatively little disturbance to the river flow. A generation capacity of up to 10MW is generally accepted as a size which fits the technical requirements to meet these characteristics. SHP is well suited for rural electrification, and many installations are not connected to a national grid but operate either for a single productive purpose or on a small standalone grid for the electrification of one or two small villages. Because of the size of the installations, the flood area is generally very small and much of the water in the river can flow unimpeded. This means that construction is also relatively fast, typically only two years, and feasibility studies can be considerably shortened. The social costs are also relatively low compared to large hydro projects, and lack of a large reservoir generally means that there is no loss of arable land surrounding the river, little damage to fish populations and no need for residents to relocate to higher land. Maintenance of the systems is also simplified, and assuming that the water flow is

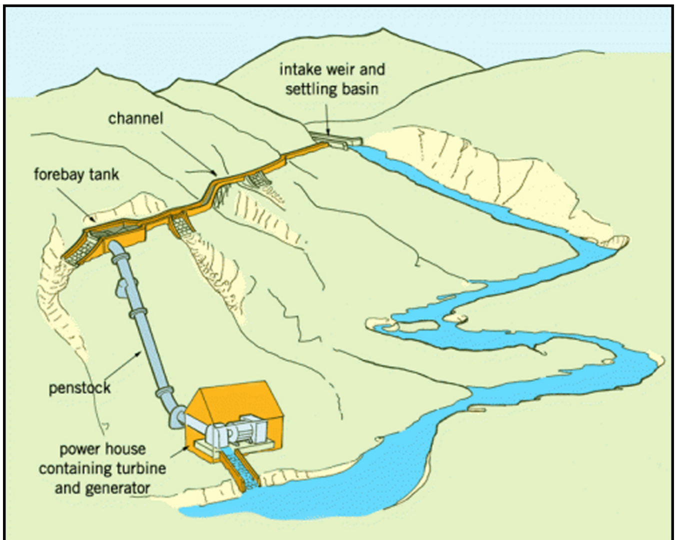

Fig. 2: **Basic SHP Plant Design** **Source: Practical Action**

kept free from debris, even a local car or motorcycle mechanic should be able to repair many problems.

Cost effectiveness

The down side of SHP compared to larger projects is the higher cost per installed kilowatt (kW) of generation capacity. While large projects can use economies of scale to achieve a per kW cost of as low as US$2000/kW, SHP plants generally come out at around $US3000/kW[1], which is usually a high price for a small village to pay, even collectively. (Note that costs are far lower if only mechanical power is used, rather than electrical.) The technology component of this cost can be reduced by selecting high-head sites if possible, where a smaller quantity of water and thus a smaller turbine can be used to generate a greater amount of energy. Unfortunately, high-head sites are usually located in sparsely inhabited mountainous regions and thus only limited potential exists.

Consideration of these costs is particularly important in poor rural areas, and the affordability of the plants is particularly valuable in developing countries where electrical energy is unavailable due to the distance to the nearest grid connection point. Working to reduce the cost is key to electrifying poor rural villages, as has been shown in the past in China and as applies today in rural Africa. Using local labour and parts further reduces the cost, and many pilot schemes make use of "sweat capital" where villagers contribute a certain number of days of labour towards the necessary civil works to divert part of the river flow. With good management, the cost of an SHP project can be as low as $1000/kW in developing countries, reducing the amortisation time to under 5 years, rather than the 10-20 years of a more expensive plant. Preferential funding with beneficial ownership and loan interest terms can further improve the economic viability of a project. In particular the low fuel cost means that SHP schemes quickly become more economical than diesel generators within just a few years.

Seasonal influences

SHP suffers from seasonal changes to river flow based on different precipitation patterns. Some rivers may regularly flood, damaging or even washing away poorly planned intake weir construction, and in the dry season flow may be non-existent or too low to operate certain types of turbines. While only good planning and quality construction materials can deal with flooding, a number of schemes are available to substitute generation ca-

Example SHP project budget
Morehead Valley Hydro A
Morehead Creek, BC, Canada

Penstock materials	$8,200.00
Penstock construction	$4,300.00
Valves, flanges, etc.	$4,000.00
Intake screen	$5,000.00
Powerhouse materials	$12,000.00
Powerhouse construction	$6,000.00
Turbine	$20,500.00
Generator & transformer	$20,800.00
Powerline (3 spans)	$2,500.00
Engineering, consultation	$9,000.00
Project Total	$92,300.00
Price per kW (32kW output at max. flow)	$2,884.00

Source: Morehead Valley Hydro Inc.
http://www.smallhydropower.com

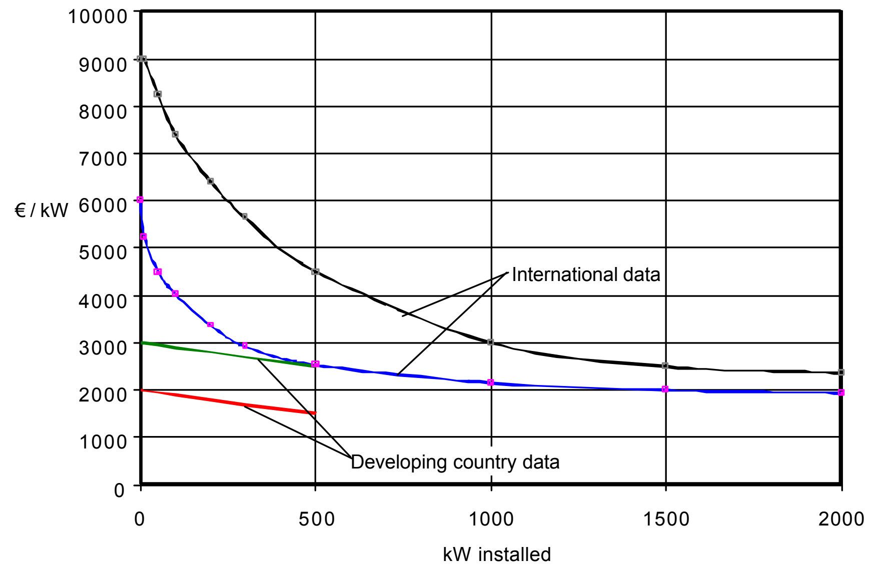

Fig. 3: Installed costs of SHP schemes Source: European Renewable Energy Council

1 Paish, O. (2002). *Small hydro power: technology and current status*. Renewable and Sustainable Energy Reviews , 6 (6), 537-556.

pacity in dry seasons. Photovoltaics in particular are a good option (for technical, if not economic reasons) because hot, dry weather means more sunlight and longer days reduce the lighting requirements in non-equatorial locations. Battery storage (or pumped storage in more ambitious schemes) charged during low demand at night or diesel generators can be used to balance load peaks going beyond the actual generation capacity of the plant. However, all this added complexity can quickly bring the economic cost of a project beyond the price of extending the national grid, and significant maintenance and operation experience is required. For this reason, each project must be assessed in detail according to the financial situation, proximity of the grid connection, the hydraulic and geological conditions and the intended use of the energy for lighting, village electrification or productive use.

Energy use

Rural villages typically initially use electricity for (indoor and street) lighting. This immediately relieves the dependence of the village on kerosene for lighting. Depending on the availability of energy-efficient bulbs, a very small plant in the range of just a few kilowatts is often sufficient to provide lighting to a few houses. Lighting systems are also less susceptible to voltage fluctuations than more technical systems such as communication systems and computers. Small systems for a few houses are very prevalent in Vietnam for example, with many pico hydro systems producing only 100-200 watts for one or two houses. The price of such systems may be as low as $50 without installation costs, but quality and reliability varies.

As more energy becomes available through larger and more communal stations, the uses of the electricity begin to diversify. Battery charging stations for mobile phones and car batteries to provide energy to off-grid households become feasible, as does basic refrigeration and television (ideal for a small cafe in football-loving countries), and the ever-popular hair dressing salons. These types of small-scale productive use may be expected to arise automatically once a reliable flat rate or meter based supply of electricity is available. At this point it also becomes feasible to begin to replace wood fires for cooking with electric stoves, although other sources of cooking energy such as gas may still be more cost efficient. Having local electricity for these tasks also reduces transport needs, as residents no longer need to travel to the nearest on-grid town to e.g. charge batteries. However, care must be taken not to overload transformers or the fragile local grid may still fail.

As power supply becomes more reliable, the growth of larger businesses can be encouraged in parallel with the generation capacity. Welding workshops and ICT centres with internet access may open, and local health care centres become more productive. The electricity can also help in processing agricultural produce, such as husking rice or grain. However, these larger scale projects require active promotion together with the scale of the plant until the skills to operate them becomes self-sustaining, and experts from other towns may be necessary for some time.

Planning and resource use

Maintenance of the plant is critical, and many sites with insufficient experience have reported the system failing due to a range of problems. The water flow must be kept consistent and free of debris, which usually requires one or two settling pools where particles such as sand may float into overflows or sink. These pools must be regularly cleared or they will soon be filled with plant matter carried by the river. The penstock intakes must also be covered with a grill to prevent larger objects from blocking jets or blades in the turbine, which can result in expensive damage. Basic wear on generator parts such as bearings may be easy to repair during scheduled down time, however care must be taken to protect both the civil works and the turbine from flooding. If a weir or penstock is washed away it will take with it much of the initial investment, and a flooded generator requires rewinding, which usually means shipping it to the nearest city where large amounts of appropriate copper wire are available. This can mean months of downtime, and the station may never come back into use.

For stations which require consistent flow levels, an agreement must be reached with the use of water for agricultural purposes such as irrigation, or the station must be switched on only at specific times if water supplies are low. Many plants fall out of use due to disagreements over the use of limited supplies of water, however good planning and feasibility studies can remedy these problems.

SHP will most likely become increasingly competitive as resource shortages, emission restrictions and taxes reduce the supply of fossil fuels. Diesel generators, while cheap and easy to install, are already less economical than SHP due to ongoing fuel costs, and particularly after an amortisation period of several years. While all generators require maintenance, a well-maintained SHP site can easily operate for 50 years, far beyond the life of most thermal or diesel generators. This means that many previously abandoned mill sites and potential new sites can be considered as new locations for SHP, increasing demand for the associated expertise and technology. This is already the case in Europe and the UK today, where the SHP industry has stagnated since the Second World War with cheaply available fossil and nuclear powered grid connections everywhere.

SHP best practices

SHP carries the potential to dramatically improve the quality of life in rural villages through a number of factors not directly measured in terms of economic benefit through productive or commercial use. This includes time saved from carrying fuel such as diesel, kerosene, charcoal and wood, improved education through lighting, less accidents involving fire, improved health through less smoke inhalation or carbon monoxide poisoning, refrigeration for food and medicine, and improved irrigation systems based on the channels created to supply the SHP plant. Not consuming any fossil fuels is also very beneficial in efforts to combat climate change, but only large numbers of SHP plants built according to broader government policy can make a measurable or meaningful contribution to climate change mitigation. These externalities are typically not counted in the pricing of an SHP project, which is why in many circumstances offering preferential loan agreements to SHP developers may be a desirable policy to pursue at a country level. The details of each particular project must be assessed however, and a number of best practices exist to ensure that a SHP station provides reliable and sustainable power to the largest number of people possible. The following section describes these practices, categorised into technical, economic and management practices.

Technical best practices

A surprisingly common error in planning SHP stations is to fail to assess the actual needs of the nearby community for electricity. A local economy which is not based on energy which may be easily supplanted by SHP will not benefit from a large SHP station. As described above, it is important to plan the size of the project according to the growing needs of the community. It is necessary to carry out a detailed needs assessment to identify what the power will be used for, and to plan development of productive industries to use increasing levels of power generation to create income in order to be able to pay the cost of constructing the plant. Without a profit generating productive use for the energy, the plant itself cannot be economic, but this does not mean that it is not desirable to build it. A number of justice-based arguments are correct in stating that rural citizens are as entitled to subsidised power as urban dwellers.

A second aspect for planning (once the scope of the electricity required and a reasonable plan including likely increases in demand has been drawn up) is the actual power available on the location. Given that the potential of any given site is limited by its hydrological features, it may be feasible to begin with a SHP site and expand capacity through other energy sources as necessary or until a grid connection becomes available, at which point energy may be sold back into the grid. In carrying out these studies, it is important to consider other uses of potentially limited hydrological resources. Irrigation, fishing, washing and even tourism must be considered as legitimate uses of a public resource, and may dramatically reduce simple estimates on power generating capacity based on water flow alone. Several cases may be identified where water flow was measured during the rainy season, resulting in the order and delivery of much larger turbines than were required or could be used[2], so flow measurements must also be taken over a period of time. It is important to negotiate the terms of resource sharing during the feasibility study rather than once construction has started.

Standardising technology and starting national or regional centres to supply the more complex components can greatly simplify SHP projects. For low head sites, standardised siphon kits can be installed in extremely short times over an existing set of river rapids, for example. Electronic load controllers to ensure a stable supply without voltage or frequency fluctuations, sealed-unit switchboards and transformers and prefabricated wiring and sockets are other examples which can greatly improve the safety of a system and reduce both

2 Loewe, P. (2010). *UNIDO Projects for the Promotion of Small Hydro Power for Productive Use*. Vienna: UNIDO.

maintenance and initial costs, and make repair and spare parts less time consuming and result in less down time.

Economic best practices

None of this eliminates the fact that electricity is a resource which must be paid for in some form. It is also important to remember that households may already spend significant amounts of time and money on sourcing other fuels such as fire wood or kerosene on an adhoc basis. Bundling this demand for energy through effective community organisation is the key to establishing a rural energy supply of any type. SHP in particular requires community organisation, as it is the long-term lowest cost solution in many cases, but only after a period of several years to accrue the benefits of practically zero fuel costs.

The most effective method of reducing the initial cost when pricing SHP systems is to use local workers and technology to the greatest extent possible. Many projects have successfully used villagers' "sweat capital" as a replacement for economic purchasing power, given that when the plant has actually been constructed, operating costs are low. Sourcing locally or even nationally manufactured turbine technology may be more difficult until sufficient momentum builds up for a local SHP industry, but avoiding a technology driven approach where sites are selected based on available turbine donations is imperative to approaching market efficiency.

While these basic technical and capital substitution features of SHP are generally well understood, actual provision of financing and subsidisation is a complex issue which must be defined at a national and even project level. From an economic point of view, SHP projects can be divided into three categories: stations which support a profitable business can generally be built first and quickest, projects for which the initial capital is lacking but sufficient user fees are available to support ongoing operation will be next, followed by purely social projects designed to extend the availability of power without economic considerations. Care must be taken to ensure that any subsidies are not simply "across the board" for all energy projects, which may result in cheap purchases of diesel generators which become more expensive within as low as three years of operation, or to avoid subsidising tariff rates directly when businesses exist which are already capable of paying the full price.

In most cases where NGOs or foreign donors seeking pilot projects are not involved, subsidisation works through "soft money" provided through preferential loans from governments, private investors or a public-private partnerships. Because of the long lifespan of SHP plants and rampant short-termism on the market, best practices often involve governments assuming responsibility for compensating private investors for the "slow" returns on their investment by guaranteeing returns up to a level which makes the loans competitive. Effective metering and transparent collection of fees is also critical to the long term sustainability of any project. Unfortunately, numerous examples of failures on this relatively simple measure alone exist. It may even be possible to bundle several SHP projects to make returns more attractive to lenders as larger amounts of money are involved and the risk of failure of any particular project distributed across the package as a whole.

Sometimes the government may provide funds for the projects directly, although it can be difficult to convince officials and particularly campaigning politicians that promises to extend the national grid to relieve energy shortages are simply electioneering and not technically or economically viable. Many of the sites to which SHP is best suited may never see a grid connection, and Africa in particular has extremely low levels of access to electrical power and generally weak governments incapable of independently providing electricity to rural areas through any means. Establishing sustainable ownership conditions of electrical utilities, providing the necessary policy and economic support and planning for what happens should the grid connection ever arrive is essential to encourage private developers to become involved in SHP construction.

Management best practices

Continuing from the previous section, any SHP project in a location with a prospect of grid connection in the short to mid term must include a plan for how the plant will be managed once grid supply becomes available. A recent Sri Lankan study found that SHP can still be economically preferable to a grid connection if the nearest branch point is over 5km away, and greater distances obviously improve the viability. However, given that energy prices to support the entire project will inevitably be higher than the (potentially subsidised) grid connection, it is extremely beneficial if the state energy company promises to either buy the plant outright at its depreciated value or continue paying tariff fees at a level capable of sustaining the plant, implicitly considering the positive externalities of SHP described above.

Ownership of the plant must also be clear from the planning stage onwards. The most profitable and sustainable plants are typically owned and operated to supply a specific productive purpose, and if this purpose arises as an afterthought to a communally owned plant, there may be resentment as to why a shared resource is being used primarily for the benefit of one company or individual. From a social perspective, it is preferable for the productive purpose which could benefit from electrical power to exist prior to SHP development, so that a separate entity can build the plant with this purpose in mind and sell surplus power to rural consumers at a socially fair price afterwards. It must be stressed again that the government's role is to provide policy support, loan guarantees and a potential option to buy the plant outright if and when a grid connection arrives, but the state power company should not be responsible for developing individual SHP stations, as they are too small and too many are required to be successfully managed by such a large entity. Plant development should lie in the hands of community groups, regional utility companies or private entrepreneurs.

This does not prevent NGOs and governments from supporting SHP through other avenues. Standardisation has been mentioned above, and creating and managing a national authority to disseminate practices in the local language and specifically catering to local and regional circumstances is invaluable. This can help potential developers understand the pitfalls of development, defuse social disputes over resources before they arrive and provide access to experienced and skilled local suppliers of components and engineering and hydrological expertise. A regional or national training centre may also become feasible, but should include not just technical aspects but also funding for e.g. bank managers and village leaders on how to handle the different financial flows required by SHP developments.

Finally, good management will result in more successful projects and more development as working examples spread. NGOs must resist the temptation to fund and implement too many projects outright and instead encourage replication. It is financially rather than socially profitable projects that will be replicated as each socially profitable project requires a donor, while financially profitable projects replicate themselves.

Summary of SHP best practices:

- *Plants should be built according to the foreseeable needs of the local community and take into consideration seasonal hydrological features and other uses of the river.*
- *Plants should be built where there is sufficient demand for electrical energy to substitute other more laborious, expensive or polluting energy sources and/or where productive, profitable and sustainable end uses are available.*
- *Plants should be built with the greatest standardisation possible with regional parts, expertise and labour, according to national and regional regulations.*
- *Because of their numerous positive externalities, plants should be protected by preferential policies where necessary and special financial structures to ensure profitability or at least sustainability after construction, without subsidising end user fees.*

The state of SHP in the world

SHP has been developed to some extent in all regions of the world. This section provides a detailed view of how and why China's SHP sector has developed so strongly over the past 50 years, followed by an assessment of the state of SHP in the other major regions of the world. The Chinese section goes into particular detail on the unique funding and policy developments which were key to the success in this market. Moving on to Africa, it can be seen that corresponding weaknesses in policy and financing areas have held back development. A brief overview of ongoing developments in Nigeria completes this section. A final overview of SHP in the rest of the world looks at South American developments and the state of SHP in OECD countries. It can be seen that there is significant potential in many of these regions for further development and efficiency.

SHP in China

SHP is spread unevenly across China with most installations in rural, mountainous or rainy provinces. Guangdong province leads with over 7000 SHP

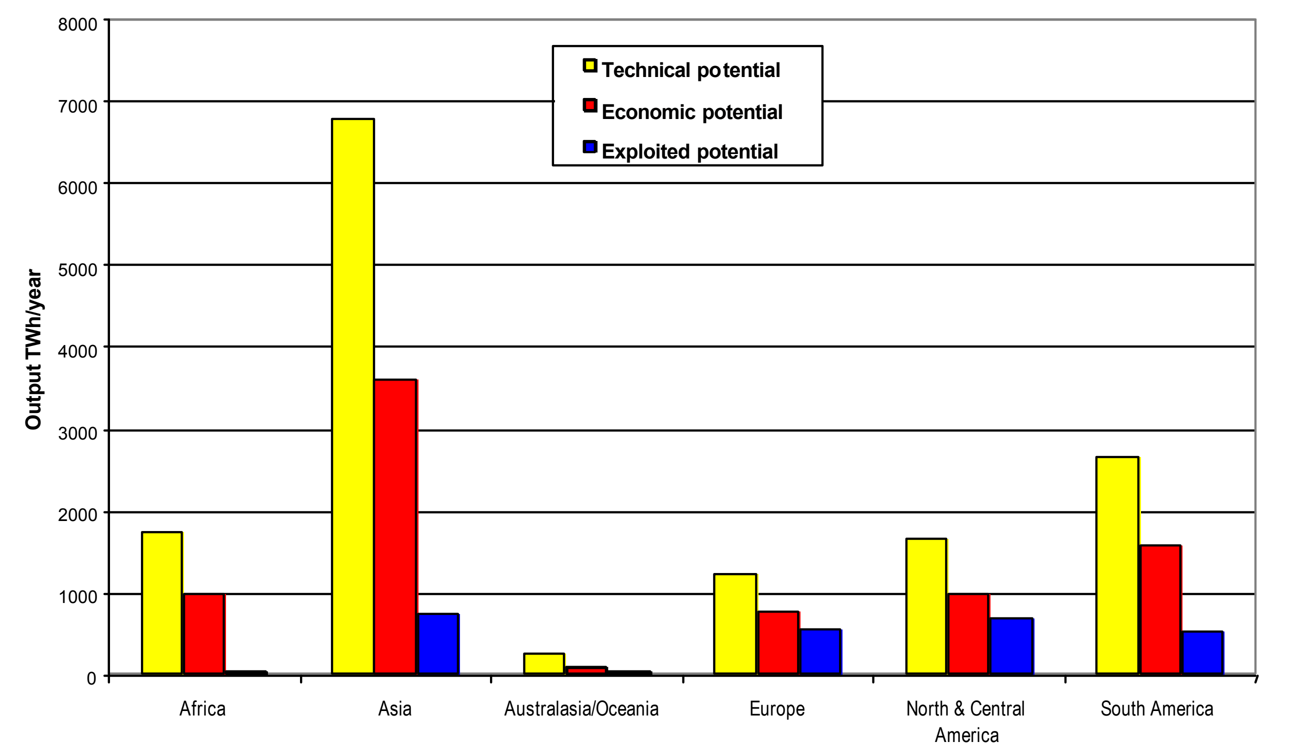

Fig. 4: Total hydropower potential by continent **Source: European Renewable Energy Council**

stations, followed by Fujian, Hunan, Sichuan and Jiangxi, each with several thousand stations and MW of capacity.

History

Although Chinese use of waterways for productive purposes has a long history, Mainland China only saw its first hydro power station in 1912 with parts provided by German company Siemens. Development of SHP in particular remained slow until the late 1960s, with most installations featuring wooden, bamboo or simple metal turbines to provide mechanical power, rural lighting and basic productive electricity. There were very few government supported installations, and technology was simple.

Fig. 5: SHP penstocks in Longyan, Fujian Province **Source: Unknown**

Government initiatives at this point included SHP in the national development plan and improved the terms of ownership of the facilities by subsidising 20% of construction costs. Devolving responsibility for construction permission and promoting local provision of materials led to a surge in building, and resulted in a spread in SHP expertise across the country, particularly in rural areas. The definition of SHP was repeatedly bumped up, from the initial 3 MW to 12 MW, 25 MW and eventually 50 MW, well into the definition of medium hydro as defined by the rest of the world. While smaller plants number in the tens of thousands, operating larger plants is generally no longer possible with run-of-the-river style installations, so dams are necessary. This eliminates many of the positive environmental features of SHP, however the dams are still largely confined to tributary rivers rather than the main stream.

Fig. 6: SHP generator operating in Yunnan Province
Source: Yunnan Digital Government

Expansion in capacity demanded greater standardisation, and in the 1970s there were over 60 turbine and complete package manufacturers in the country to meet the construction demand for the new projects. This effectively ended custom-made wooden and iron installations, which were replaced with pre-fabricated components conforming to Chinese national standards. SHP plants which previously operated independently or in village grids were upgraded with new turbines and connected to ever expanding regional grids. The voltage and transmission capacity was also increased to reduce transmission loss. By 1979, SHP provided the primary power supply for basic domestic lighting for 300 million people in rural China[3]. China currently boasts the most widespread deployment of SHP plants in the world today, with over 40,000 stations generating a total of over 55GW of installed capacity[4]. This constitutes 40% of the installed capacity in the world today, and construction continues apace.

There are several reasons behind the success of SHP in China. The preferential government policy is no doubt the most important: this includes policies on loans, tax reductions and grants which have been in place and constantly revised for over 50 years now. Nevertheless, central government ownership remains low, and investment from regional grid corporations covers the majority of the costs of establishing an SHP station. This leads us to examine the groups who decide to develop SHP stations.

Policy and lending practices

In China, the Ministry of Water Resources controls the Bureau of Rural Hydro and Electrification, which sets broad policy targets for SHP resources, construction and management. However, the ministry devolves responsibility for implementation of these goals to province, prefecture and county levels, each of which operates its own academies, maintains a regional development plan appropriate to the different levels of development and sources technology and materials locally. All management involves local government, local companies and local people at all stages of the process.

3 Tong, J. (2004). *Small Hydro Power: China's Practice*. Beijing: China WaterPower Press.

4 Hangzhou Regional (Asia-Pacific) Center for Small Hydropower. (2009). *Rural Hydropower and Electrification in China*. Beijing: China WaterPower Press.

While in the past funding was typically provided by the government and "sweat capital", the Agricultural Bank of China and China Construction Bank took over responsibilities for loan handling in the 1980s with packages tailored specifically to the needs of SHP developers. Soon, specialised banks, private shareholding systems, foreign investment, joint ventures and build-operate-transfer mechanisms have been introduced as suitable to different projects. When state-owned stations become operational, government policy requires a "electricity supports electricity" policy which directs a certain amount of profit to be put aside for new construction. There is literally no project too large or small to find some level of funding.

Literature on the subject highlights the lessons China has learned in deploying SHP on this scale. Initial bottlenecks were soon found to be due to centralised decision making and supply chains. Because the civil works to prepare for SHP are generally quite short, it is important to have a highly responsive supply chain to provide SHP equipment, and a decision was soon taken to devolve responsibility as described above. The somewhat controversial tactic of increasing the MW definition of SHP, while reducing the environmental benefits of run-of-the river systems, has also resulted in more profitable plants. This allows utility companies to assume responsibility for developing sites at the lower MW range of what would normally be the responsibility of large state-owned hydro enterprises. This results in better capitalised regional utility corporations coming together to fund further construction.

Finally, separate development and promotion of SHP and LHP is essential in the early stages of a national SHP programme. SHP is relatively simple technology that can be developed and maintained by rural people. It is these experiences which China is particularly well positioned to transfer to developing countries around the world.

SHP in China today is considered to have entered a "third phase" where it is promoted for environmental purposes. With the national electrification rate approaching 100%, the concentration has shifted from using SHP to provide simple lighting, fuel wood substitution and productive purposes to development as a substitute to more difficult, expensive or polluting projects such as large hydro, nuclear or coal power[5]. Development is supported by websites such as shp.com.cn for ample information and access to experts and internal technology transfer for the domestic market.

This section closes with a brief overview of the SHP sector in China. Recent information[6] obtained from the IC-SHP, an international organisation in Hangzhou focusing on the study and promotion of SHP, puts forward the following measures:

- *55,000 installed MW (equivalent of 2x Three Gorges Dam)*
- *0.66 million people employed*

5 Hangzhou Regional (Asia-Pacific) Center for Small Hydropower. (2009). *Rural Hydropower and Electrification in China*. Beijing: China WaterPower Press.

6 Liu, H. (2011). *ICSHP and Its Activities*. Hangzhou: IC-SHP.

- *Constitutes approx. 30% of renewables in China*
- *Half of the territory, one third of all counties and one quarter of the population rely on SHP for primary power*

SHP in Africa

African SHP is the least developed in the world, with recent estimates by the African RC-SHP in Abuja (a regional organisation affiliated with the IC-SHP) finding only 478 sites with identified SHP potential, much less any concrete developments[7]. Over 50% of these sites are in Nigeria alone, a sign of the strong local focus of the RC-SHP. There are no reports of significant use of cheaper pico hydro units (as described in the following section on Asia) to provide power to families.

Only 10% of the African population has reliable access to electricity, with the overwhelming majority resident in the extreme north and south[8]. The rural demographics of the African population and a weak electrical grid system makes Africa an excellent candidate for dispersed, off-grid power generation through small-scale renewable energy developments such as SHP. The relatively low cost and large undeveloped capacity means that SHP could, in combination with other renewable energy sources, electrify a great deal of the continent in a relatively short time.

The benefits of this would be numerous. Deforestation and clear cutting for fire wood would be reduced as electrical stoves gradually replace wood fires for food preparation, and domestic lighting and thus also education would improve. Health, particular cancer cases, are also affected as less wood smoke particles are inhaled in confined spaces. This pattern is well proven, as evidenced by the progress in rural China over the past 50 years.

Obstacles to development

Serious obstacles to large-scale SHP development are the availability of technology, expertise and financing mechanisms. Very few central African countries have the capacity to build hydroelectric generator sets, and even the most advanced such as Nigeria and Kenya are only on the verge of beginning local construction today. Pilot projects surveyed or carried out by the IC-SHP report difficulties in sourcing key materials such as quality concrete in sufficient quantities in rural areas. Local engineering expertise is also lacking in some countries, with a great deal of the educated population resident in the Western world in order to support families through remittances. Nigeria has taken significant steps to remedy this problem by establishing a regional SHP base (RC-SHP Abuja) with the support of UNIDO, and engineers with SHP experience, often trained at the international organisations in Hangzhou, are now available in many countries. The RC-SHP also publishes booklets on

7 UNIDO - RC-SHP. (2011). *Regional Centre's Profile*. Abuja: UNIDO - RC-SHP Nigeria.

8 Kalitsi, E. A. (2003). *Hydropower Development in Africa*. Johannesburg: NEPAD.

best practices for SHP in Africa, which include key sections on funding and policy.

Yet it is financing and policy which remain the most serious problems even in countries such as Nigeria taking firm steps towards widespread SHP deployment. The wide variability in availability of civil engineering skills, specialist SHP engineering skills and actual SHP equipment results in a lack of clarity when preparing feasibility studies and budgets. The result is a difficulty in financing even profitable plants due to levels of uncertainty unacceptable to lenders. Government policy also works against any community organisation to develop river resources into SHP by reserving authority for the provision of electricity to government agencies only. This policy forms an identifiable pattern of weak development in all countries in which it is pursued. China has significant experience in the devolution of government power for rural electrification, and a focus on transferring the results of these experiences has the potential to be extremely beneficial for Africa.

These combined problems currently give large hydro developments a distinctive advantage in Africa, as projects of greater value attract higher quality feasibility studies and foreign investment. Many large developments are carried out as "gifts" by donors such as China, which although politically impressive, has a minimal or even negative effect on rural electrification as SHP and other dispersed renewable energy sources receive less and less attention.

SHP in Asia

Fig. 7: Chinese-made 100W "family hydro" turgo turbine in use in Vietnam Source: Oliver Paish

Asian countries have extremely varied levels of development and electrification, and this is reflected in the state of SHP in this region of the world. Electrification rates range from as low as 2% or 5% in Afghanistan and Myanmar respectively up to 87% and 96% in the Philippines and Malaysia, for example[9]. The rich river systems in the region make SHP development the ideal choice for robust and low-maintenance systems in a region with very high rural populations such as Southeast Asia in particular.

Countries neighbouring China have been able to take some advantage of the Chinese experience with SHP, however this has mostly been limited to cheaply available technology rather than organised cooperation programmes. In Vietnam, for example, tens of thousands of pico-level "family hydro" systems are estimated to be in operation with most producing only 100-500 watts[10]. Nepal and Sri Lanka have more developed systems in place with local production and expertise for larger micro or small level hydro plants, but statistics on exact levels of power provision and existing installations are sparse. Sri Lanka in particular has an industry sufficiently developed that it has begun exporting

9 Zhu, X. (2008). *Status Quo and Problems of Small Hydro Development in Asia-Pacific Region*. Nanjing: Hohai University Press.

10 Paish, O. & Green, J. (2005). *The Pico Hydro Market in Vietnam*. Hampshire: IT Power.

technical components and expertise in cooperation with some African state electricity companies.

India in particular deserves to be singled out for making ongoing efforts to promote SHP, however the resulting development has not been as rapid as the Chinese case. A regional SHP centre supported by UNIDO and the international SHP centre in Hangzhou, China has been providing training and consulting services for SHP developers since 2003 in the state of Kerala. However, despite government policies allowing private or public-private development of SHP, funding has been slow to materialise and more financial creativity is required to really boost rural electrification, which stands at around 43%. It should be noted that privately owned wind power in India has seen significantly more success.

With the exception of developed countries such as Japan, most Asian nations suffer from either central control of SHP development or a (central) government monopoly on all electrification developments. For reasons described in more detail below, this is less than optimal for the highly dispersed style of electricity generation provided by SHP. Obtaining permission to use a river, on the other hand, is relatively easy in many of these countries, or currently not regulated at all.

SHP in the rest of the world

Europe

SHP was widely developed in Europe prior to and during the industrial revolution, primarily in the form of hydro powered mills which were then converted for electricity generation purposes. Hydro potential in general is highly developed in Europe, with the majority of technically feasible sites and by some estimates 82% of economically feasible sites already developed in Western Europe. Development in Italy, France, Spain, Germany and the UK is particularly high, and around 16,000 SHP plants are estimated to be actively producing power in the EU today[11]. Levels are considerably lower in the newer member states, but in all states tapping new sites for installation of hydro power of any kind is extremely difficult due to stringent resource regulation, and the market for SHP has stagnated in recent years. Manufacturers appear resigned to the prospects of a shrinking market, and many have gone out of business or merged into larger corporations which focus on export markets. European turbines in particular are renowned for their high efficiency, but also notoriously highly priced.

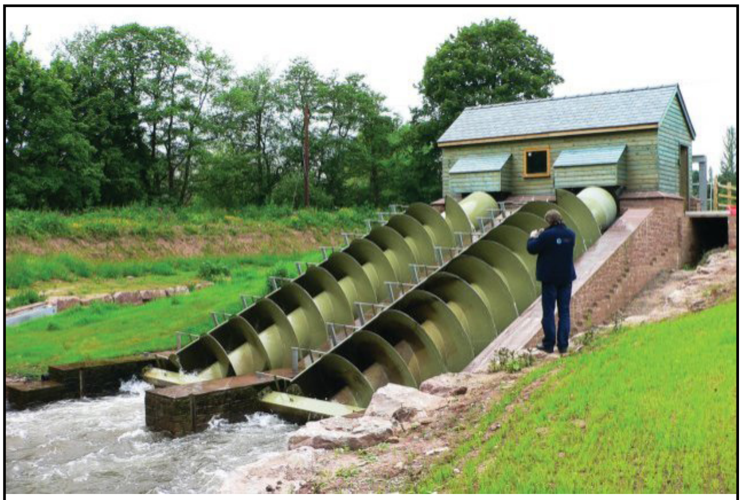

Fig. 8: An innovative Archimedean screw installed at an old mill site in the UK. While efficiency is slightly lower than regular turbines, the design allows fish of all sizes to pass unharmed through the slow moving screws Source: Engineering and Technology Magazine

11 Thematic Network of Small Hydro Power. (2004). *Small Hydropower Situation in the New EU Member States and Candidate Countries*. Vilnius: Lithuanian Hydropower Association.

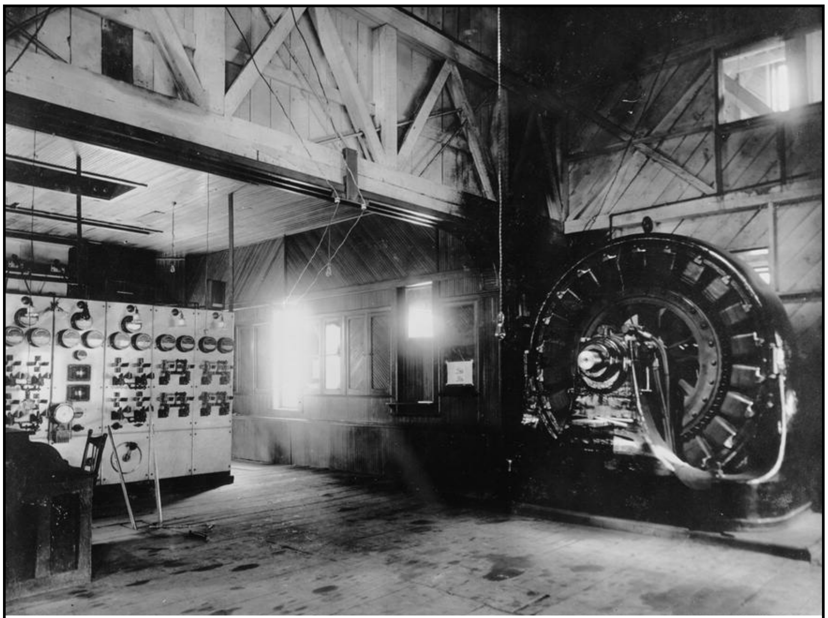

Fig. 9: **Pelton wheel and generator at the Ames Hydroelectric Generating Plant, Ophir, Colorado. The set, produced by General Electric, has been in operation since 1905.** **Source: Library of Congress**

Chinese turbines with only slightly lower efficiency and quality are available for a fraction of the cost and are much more popular around in developing countries for the higher price/efficiency ratio.

The European Commission strongly supports the development of renewable energies through directives and preferential policies, however this frequently conflicts with the needs to preserve fish migration paths and environmental concerns. NGOs often raise objections to hydro development of any kind, despite the relatively minor effect of SHP on the environment. As a result, there are two main markets for SHP in Europe: the western market, which focuses on refurbishing aging plants, and the eastern market, which is seeing ongoing development of new projects. With 70% of SHP plants over 40 years old (and 50% over 60 years) in the old member states, many plants have become uncompetitive and can be brought back into productive use through relatively minor investments. The UK in particular has a great deal of low head former mill sites, and creative solutions involving standardised siphon penstocks and reaction turbines are being developed at universities[12]. Around 4000 MW of SHP capacity was added in the last ten years, most of it in Eastern Europe, and around 15,000 people are employed directly or indirectly in the SHP sector.

North America

In North America, the definition of SHP also stretches up to 25 or 30 MW, in Canada and the US respectively. The effect is similar to that described above for China: larger plants are constructed by utility companies, and higher returns ensure bank loans are available to finance construction. Smaller installations are increasingly relegated to do-it-yourself users and very isolated communities. The sheer size of North American countries means that despite the high level of development, the population density remains some of the lowest in the world and SHP can be a viable solution for very isolated communities, particularly in Canada where diesel is often the main source of power. DIY SHP has a growing following in the US for home power generation, together with other "fashionable" renewable energy sources, even where grid power is available. This has grown to the extent that popular culture and even TV series exist to promote green living and user-installation of alternative energy sources as a practical home activity. Similar to the UK, these are frequently built at old mill sites where minimal civil works are necessary to begin generating power.

12 Paish, O. (2004). *Technical innovations in low head hydro*. Duffield: Derwent Hydro.

South America

The electrification rate in South America is generally much more consistent than in Asia with most countries achieving around 80%[13]. However, difficult terrain and remote populations in many of these countries mean that achieving full electrification from the grid is a remote prospect, and stand-alone or mini-grid renewable solutions once again present the lowest cost solution to rural electrification. SHP certainly has a role to play in this region, a fact recognised by the establishment of a regional SHP sub-centre in Colombia with close links to ESHA and the Hangzhou IC-SHP. This centre, known as CELAPEH (Centro Latinoamericano para la Pequeña Hidroeléctrica), focuses on electrifying rural areas beyond the reach of the grid. The prospects for SHP in Colombia are particularly interesting due to difficulties in reaching millions of people (approx. 4% of the population) living in remote Andean areas beyond the national grid. These areas, known as the non-interconnected zones (ZNI) are primarily served by poorly serviced diesel generators in the 100kW range. The significant SHP resources in these areas present an ideal opportunity to demonstrate the ability of SHP to substitute expensive and inefficient fossil fuel supply chains with cheap, renewable energy.

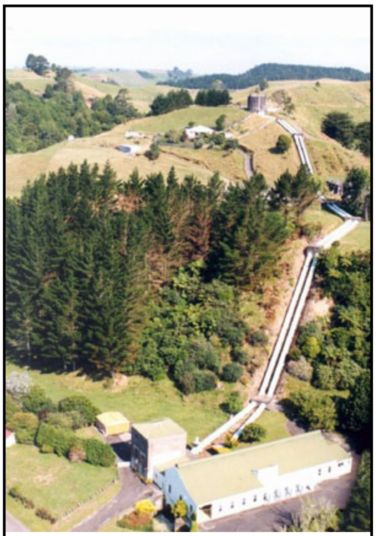

Fig. 10: 4.5MW SHP station in New Zealand. Source: TrustPower

Pacific

Australia, New Zealand and small Pacific Island nations have also deployed SHP. New Zealand in particular provides an interesting case due to its 60% dependence on a wide range of hydro stations for base load generation. Geographical constraints on generation locations and limits in the transmission system resulted in a five-week blackout in 1998 in New Zealand's largest city, Auckland – a dire warning against poor planning of the national grid and over reliance on a single source of energy. Nevertheless, the majority of the country is dotted with hydro plants of all sizes, and SHP plays an active role in distributing generation capacity across the country, thus reducing transmission costs and increasing efficiency and resilience.

Middle East

Due to abundant oil resources, hydro deployment in the Middle East has been relatively low, and SHP plants are practically non-existent. There is little information and nearly no recent statistics available.

Replicating China's success

As sustainability and reducing emissions has increasingly entered global consciousness as an imperative necessity, a range of initiatives have been brought forward to attempt to replicate China's success in SHP in regions around the world. As described above, an SHP industry already exists at some level in most developed countries, so it is developing countries which stand to benefit most. Countries with low levels of rural electrification and a temperate, mountainous climate which makes grid expansion difficult and regular fuel supplies for diesel generators expensive present ideal opportunities. SHP can dramatically improve quality of life and prevent deforestation for fuel wood

13 Zhu, X. (2008). *Status Quo and Problems of Small Hydro Development in Asia-Pacific Region*. Nanjing: Hohai University Press.

while generating power with practically zero GHG emissions. The unexploited potential is so great, and the technology and development model so reliably proven, that nothing less than an energy revolution in as short as 10-15 years is possible in some target countries.

This section will focus on the key features of the Chinese model which have yet to be replicated in developing countries, coming to the conclusion that policy and funding difficulties are the main problem, followed by underdeveloped local expertise and manufacturing capacity. I then examine where efforts at technology transfer and capacity building have been successful and where improvement is needed, and look at what can be changed to spur progress in this direction.

China's success in contrast

Ownership and policy

The previous discussion of the difficulties in developing clear policies regarding ownership of power generation facilities in China is currently also a significant barrier to the spread SHP in developing countries, particularly African countries. Most countries are currently characterised by a government monopoly on electrical development, which is justified in terms of guaranteeing pricing, availability, standards and safety. Unfortunately the administrative constraints of this approach limits the capacity to only large projects which usually require high levels of supervision and can tie up entire government departments for decades. These projects are almost universally implemented with the intention of supplying large (capital) cities with power, to the detriment of rural populations. Rural supply is usually not considered, and is in any case difficult and prohibitively expensive to implement with such installations due to transmission losses. At costs reaching thousands of dollars per kilometre of grid extension, small hydro development in unelectrified rural areas is far more efficient and attractive. There is also a focus on cheap projects (coal) and profitable projects (large hydro), generally at the expense of the environment and fishstocks, and requiring resettlement of floodplain residents. At the same time however, government policy prevents rural residents, communities, private utilities and even some regional governments from developing and owning potential SHP sites to address their own energy needs.

In China, this problem has been resolved by devolving authority over small developments far down the chain of authority. The central government is responsible only for setting development targets, which has the effect of giving regional authorities much more leeway to meet the different needs and levels of development of their own populations, regardless of whether the central targets are met or not. This "Government Enabled & Market Based Approach" has proven highly successful, and little reason exists not to replicate it in developing countries around the world. A similar effect has been achieved in Western developed countries, albeit through a different route of privatisation first, regulation later.

Another success in the early years of China's SHP programme is known as the "Three-Self Policy", which basically recommends self-construction, self-ownership and self-utilisation of SHP plants and the electricity they generate. This can be expected to complement the break in state authority over small development projects by giving rural residents a direct interest in the projects and a degree of control over SHP developments and thus also their quality of life. While this policy has been implemented in some countries, notably India, it must be adopted together with financial tools to push initial SHP development until momentum is sufficient to drive ongoing independent development. In particular, a local manufacturing base and technical expertise is critical.

Economics and funding

Moving on to economic matters and keeping with the theme of development momentum eventually driving development on its own, some form of economic "push" must be present in the nascent stages of SHP development in any country. Developing countries in particular experience a lack of capital to move away from traditional or current levels of energy production no matter what the level of national development. While most residents and governments understand the problems of "addiction" to fossil fuel thermal plants and how chopping fuel wood causes deforestation, there is little incentive and no capital to drive change.

Having provided strong policy incentives to promote SHP early in its development, China moved through a range of models to fund the development. Again it becomes clear that different approaches are necessary at different levels of development. At extreme levels of poverty and low development, rural residents can only contribute what time they may usually use collecting fuel and potentially what money they spend on diesel or kerosene for energy. Most African countries with potential for SHP are at this level of development. These funds are often sufficient to cover running and maintenance costs of an SHP plant, but initial capital must be provided by the community, regional or national government or foreign investors/donors. It may be most economical to build plants to provide mechanical energy only and later upgrade to electrical energy when a productive purpose for energy in this form is available. In Nepal for example, some plants provide mechanical power to husk rice by day, and drive a generator for village lighting by night.

At higher levels of development, rural energy utilities can be encouraged to assume responsibility for developing SHP in a region. At this level, local grids and some national grid feed-ins may be expected, and many stations will begin to turn a profit. Plowing profits into construction funds for new plants (a policy at one time in China required 20% of profits to be used to fund new SHP plants) can result in extremely rapid SHP growth. This should not be of concern to government power supply monopolies, as careful taxation can ensure that revenue is collected while still spreading the benefits of clean electrification within a country. Profitability is a strong driver for further development, and a national industry can be expected to be self-sustaining at this point. Export activities may begin soon thereafter, and in Africa in particular, the potential for local cooperation is enormous due to the large number of countries and high rural populations.

China currently has rural populations served by SHP plants at all of these levels of development, and the potential for cooperation and capacity building in these "soft" and non-technical policy and financing areas is significant. Unfortunately efforts in this field have traditionally been weakest. This will be discussed further below.

An often overlooked feature in rural electrification is the ability of a government to enforce development policies. Having sufficient control over banks to be able to mandate the types of loans necessary to promote SHP is important, as is the ability to credibly guarantee utilities a fixed feed-in tariff when they are finally connected to the national grid. Corruption can quickly scuttle policy-based efforts to solve the difficulties of rural electrification, particularly when the goal is to move away from fossil fuels while powerful national lobby organisations with plenty of money continue to promote their fossil fuel based business models.

Finally, technical differences in the capacity to develop SHP stand out between China and the developing world. Technology transfer is a field where China has considerable experience and a growing history of excellence in providing engineers from African countries in particular with the skills necessary to develop SHP. The following section covers this topic in more detail.

Institutionalised cooperation

A number of institutionalised bodies have sprung up to address and organise cooperative work on the development of SHP around the world based on China's experience. The most recent high-level meetings have resulted in the Hangzhou declaration and the FOCAC Sharm el-Sheikh Action Plan. The organisations charged with implementing these declarations range from UN-supported organisations such as UNIDO and the IC-SHP to the private investors working with institutional support.

Political declarations

Beginning with the broadest measures, the Millennium Development Goals focusing on poverty eradication implicitly rely on infrastructure capable of supporting non-subsistence employment. Rural electrification clearly plays a role here, particularly with many African states well below a 10% rate of electrification and the African average standing at only 37.8% in 2006, with sub-Saharan countries averaging far lower. This has been recognised at several high-level meetings attempting to establish a development course for African states. As part of these efforts, the Forum on China-Africa Cooperation (FOCAC, established in 2000) met for the fourth time in late 2009 and released a declaration ranging from political and security affairs to the economy, cultural exchanges and agricultural development. Significant funds were promised to support "major infrastructure projects" and firm agreements on technology transfer in the field of clean energy were obtained. 100 pilot energy (including SHP) and water supply projects were proposed[14]. SHP can clearly play a role in meeting these ambitious goals, and the institutional structure is in place to do so, however actual pressure from the uppermost levels is more focused

14 FOCAC. (2009). *Sharm el-Sheikh Action Plan*. Sharm el-Sheikh: FOCAC.

on economic cooperation and large "friendship" style infrastructure projects rather than actual cooperation which would benefit rural electrification. In the academic discussion following the meeting, Li Anshan of Beijing University singled out technology transfer as the key aspect holding back economic development in Africa, and urged the Chinese government to further promote this aspect of the China-Africa relationship.

With a more specific focus on SHP, the Third Global Forum on "Hydropower for Today" released the "Hangzhou Declaration on Promotion of Small Hydropower in Asia and Africa" in June 2007. This largely technical meeting resulted in several declarations to promote cooperation, including a proposal to rename the IN-SHP to the IA-SHP as well as a "massive project" known as Lighting Up Africa. The declaration correctly identified all the points of action also identified so far in this study, including technology transfer, skillset building and on-site assistance, and policy change. Actual action has been far more limited, and the only references to this project are to be found in the initial press releases. Interviews identified a number of pilot projects underway (e.g. a development in Zambia managed by the IC-SHP directly), but carried out mostly by Chinese engineers and using imported components, including even concrete. The embedded policy problems in African countries are far greater than this, and institutions must recognise this as the primary goal rather than continuing with simple technical trainings and assisting with the construction of pilot projects.

Institutions and organisations

As the prime SHP authority in the world, much is expected of the International Center on Small Hydro Power (IC-SHP) to rise to these problems. The organisation receives funding from both UNIDO and the Chinese Ministry of Water Resources, and is expected to increasingly receive compensation for its activities around the world. There is a close cooperation with a SHP equipment manufacturer, which is the automatic recipient of any SHP hardware contracts, as well as the HRC-SHP, a regional organisation which also runs regular training programmes. These two organisations have a strong technical focus, and the majority of the staff come from an engineering background with detailed knowledge of Chinese practice – all but one or two of the IC-SHP's 25-strong staff are Chinese. However, as a result, the organisation has little experience to offer to governments regarding policy change and organising financing for SHP. Even its technical assistance is frequently described as unsuitable to the needs of the recipient countries as engineers simply assume that social problems caused by hydro developments or developing corresponding demand will be resolved by the implementing governments, as is usually the case in China.

Fig. 11: The IC-SHP building in Hangzhou, China **Source: IC-SHP**

While the level of technical support offered to African countries is on par with the status quo in China, the Hangzhou organisation must consider whether deploying this level of advanced technology makes sense without ensuring a locally embedded capacity to maintain and repair such equipment. Unfortunately, short visits and a lack of understanding of these circumstances means that the work of the IC-SHP in Africa has been less than satisfactory to date.

The institution closest to African governments and with the capacity to push for the required policy change is the RC-SHP in Abuja, Nigeria. Established in 2006 and funded by the Nigerian government and UNIDO, the organisation's mandate is to promote SHP for sustainable development and to carry out training and capacity building for SHP in Africa. The RC-SHP appears to have some influence over policy within Nigeria, however it is unclear what the relationship is with neighbouring countries, which will probably wait to see the success or failure of attempts to promote SHP in Nigeria first. A number of publications describing best practices for SHP policy in Nigeria are also available on request, but not directly online.

To date, the RC-SHP in Africa has researched the state of SHP in Nigeria and established a pool of experience and knowledge with which it has successfully started planning for several SHP plants in the country. It is beginning to have a regional influence by identifying potential sites outside of Nigeria and offering technical assistance where necessary. This activity should be expanded as much as possible, together with a new focus on advising governments on policy changes to make SHP development attractive for regional governments.

A transition is currently underway to turn the RC-SHP into a public enterprise with a view to eventually becoming a self-sufficient unit capable of providing paid consultation services. This step may be premature given the nascent state of African SHP, and no clarification of why such a move is necessary was given. It may be desirable for the IC-SHP to focus more specifically on African development for some time together with the RC-SHP in Nigeria in order to establish a serious foothold on the continent with regard to skills, policy experts and manufacturing capacity. However, until now, most of these organisations have worked independently and with a strong focus on technical trainings as described in the following sections.

In conclusion, a promising range of institutions is present on the scene with funding adequate to move forward with their mandate. Greater creativity is necessary by these organisations to secure funding beyond their UNIDO and national grants, and a more activist focus on creating policy attractive to SHP development will go a long way towards increasing demand for their services. Management issues, described in more detail below, may be holding back progress towards these goals.

Training Programmes

History and content

The first official organisation to focus on international dissemination of SHP knowledge was the HRC-SHP in Hangzhou, China. Together with the IC-SHP, these organisations have over 25 years of experience in coaching foreign nationals in SHP development according to the Chinese model. Trainings are conducted at least twice per year at each organisation, with up to 50 participants from around the world, particularly from Africa, Southeast Asia and states from the former Soviet bloc. The training events range from short meet-and-greet visits for government officials completed in one day to longer 2 month stays for in-depth study of the technical aspects of SHP. Training is carried out exclusively by Chinese tutors either from the institutions in Hangzhou or from four "bases" with which the IC-SHP maintains contact within China. Training is in English or Chinese, with translators provided for seminars conducted in French and Russian.

Fig. 12: East European trainees learn about turbines at the HRC laboratory
Source: HRC-SHP

No previous students have returned to become trainers in their own right at the centre. Using Chinese experts to describe China's success in SHP is clearly a useful approach, but the applicability of these experiences to the rest of the world is questionable. Chinese experts have little or no experience with the local geological, hydrological, climatic, social, cultural, financial, political, legal, educational, linguistic, professional and market situations in the target countries, and some specialisation is necessary to be able to deliver a training that does not need to be completely reformulated to meet local needs. The establishment of regional centres goes a long way in this direction, however Chinese engineers with little knowledge of the pitfalls of SHP projects in rural areas of countries with extremely low levels of development are unable to provide trainings which benefit visitors from these countries. Clearly, exchange on more levels is necessary between the sinocentric Hangzhou organisations and their target countries. A recent UNIDO report in fact stated that cooperation initiated by Sri Lanka, a developing country with relatively low but increasing level of SHP experience, was able to interact with Rwandan developers far more effectively and implement projects that resulted in real, rather than theoretical learning.

While policy issues and finance are covered at the trainings, there does not appear to be any specific push to draw in policy makers such as energy ministers from the target countries. SHP engineers may understand these needs, but they are not in a position to make such broad changes at home, and many report frustration of being unable to implement what they have learnt. The Hangzhou organisations could dramatically increase their impact in the developing world by running training sessions specifically targeting and inviting ministers and bankers from these countries. Rather than focusing on technical issues, these special trainings could explain the benefits of promoting policy friendly to rural electrification to the economy as a whole, and describe China's innovative funding practices to the people who actually have the capacity and "clout" to make changes when they return home.

Ongoing contact

Interaction upon returning home could also be improved – most trainees lose all contact with the IC-SHP other than an irregular newsletter delivered by email. This newsletter contains details on visits by the director of the centre, conferences and events held in China, and cut-and-paste introductions to supporting organisations. Newsletters with this content are of limited use to trainees, and could be improved if contributions were actually written by people with an understanding of the needs of SHP developers in the recipient countries. This has been suggested by the RC-SHP in India in 2003, but has yet to be implemented. Some trainees report ongoing contact with the IC-SHP for the purpose of turbine purchases or donations, but there is no forum or similar system through which graduates may discuss their specific projects with tutors after they return home.

Trainees often write reports of their experiences in Hangzhou in China, and are very enthusiastic about their experiences. The field visits, in particular the Three Gorges Dam, are very popular, and all trainees claim that they feel very much at home with the facilities and are given ample opportunity to communicate with their families back home during longer stays. The technical content of the courses is of a very high quality but trainees report that they struggle to implement what they have learnt at home due to a disparity in the quality of construction materials and funding problems. Given the circumstances, it may be more beneficial to teach methods applied by China in the recent past rather than the current standards of SHP in use in China today. A simple method to this end would be to educate the trainers on the situation on the ground in many African countries prior to setting the training curriculum. This would give the Chinese side an opportunity to creatively engage with the specific problems of their students, rather than leaving this adaptation step entirely up to the trainees. Finally, trainees often request and could clearly benefit from an online repository of the training material they study during their stay in Hangzhou. Such reference material would simplify reproduction of material collected at the courses for SHP leaders when they return to their home country. The "Info-Center" on the IC-SHP website lends itself to this purpose, but is currently limited to conference announcements and news of projects in China which have received CDM funding, but no information on how developing countries might receive similar funding or other information pertinent to SHP in the developing world. In all, the training and follow-up offered by the Hangzhou organisations retains a distinctive inwards focus on Chinese practice, rather than trainings customised to the needs of the international students.

Fig. 13: African trainees examine an HRC electronic load controller fitted to a turbine in Shaoxing, Zhejiang province Source: HRC-SHP

The overwhelmingly Chinese staff of the Hangzhou organisations form a part of this problem, which could be resolved by diversifying their experience and background. The IC-

SHP employs approximately 25 full time staff, of which all are Chinese except one or two (usually European) foreign interns. This is disappointing for a UNIDO-supported "international" organisation. Hosting and employing full-time African specialists would go a long way towards furthering understanding between the needs of both countries, and move the development culture away from simple donation and aid, towards genuine long-term cooperation. Long-term exchanges between organisations have also been suggested, but not yet implemented due to an unwillingness to be away from family and funding issues.

In conclusion, the Hangzhou organisations have a strong history of carrying out remarkably detailed trainings on all aspects of SHP. The focus so far has been on engineering visits and technical capacity building, however without political and financial support for SHP projects, these skills are seldom put to use when trainees return home. Diversifying the staff of the Hangzhou organisations to more directly target the problems faced by African trainees in particular and specifically pursuing responsible government ministers and managers of potential funds is necessary to truly fulfil the mandate of the IC-SHP.

Local visits

Purpose and duration

The Hangzhou organisations regularly organise visits for Chinese specialists to foreign countries. Travelling in small teams of 2-3, the visits are typically around 2 weeks in length and are used to support projects in the target countries and sometimes carry out similar training events to those held in Hangzhou. Most visits are for assistance in feasibility studies, although involvement in some projects in the past has continued through to design, construction supervision and equipment supply. The IC-SHP has a particular focus on Africa for these visits, although there have also been several to the South American region, Southeast Asia, North Korea and Papua New Guinea.

UNIDO reports single out these visits as a cause of problems rather than solutions due to poor preparation and engagement with local conditions. There are no records of government officials visiting to promote or explain SHP-friendly policy cooperation, and engineering visits have repeatedly failed to consider the economic, social and consumption aspects of an SHP development[15]. It is also pointed out that the visits frequently result in substandard feasibility studies due to non-representative flow measurements made over the exceedingly short period of the visit, or failure to communicate with locals about their needs resulting in a lack of consideration of other uses of the river. Some visitors reportedly struggled with language differences and wild local conditions and temperatures. These problems were then compounded when generators donated to meet specifications determined during these visits were entirely unsuitable to the situation on the ground. Some were also impounded due to a failure to consider that import duties must be paid. Local teams

15 Loewe, P. (2010). *UNIDO Projects for the Promotion of Small Hydro Power for Productive Use*. Vienna: UNIDO.

eventually searched for other sites based on the available turbines, rather than acquiring turbines suited to the already existing potential sites.

These issues could be surmounted by specifically briefing visiting specialists on the conditions in the recipient countries in question and focusing on adapting the measures China took 50 years ago in the past to the local conditions. This requires a change in behaviour of specialists accustomed to routine work in China. A greater focus on visits designed to change the national development atmosphere for rural electrification, rather than visits supporting individual projects, should be the long-term goal of the Hangzhou organisations.

Longer visits

Longer visits are currently reserved for construction teams working on pilot projects, such as the current case where the IC-SHP has been contracted as a developer for the Shiwang'andu project in Zambia. Such visits, if they become regular, could be extended to place a Chinese specialist in a shared management role with an African developer. Interviews have shown that while transfer of management skills is limited in pilot projects due to Chinese specialists assuming management responsibility, the longer visits result in closer social ties and respect even amongst construction workers, particularly in countries where local laws require local labour to be hired in addition to Chinese workers. While workers may be reluctant to leave home for the 1-2 year periods it takes to fully implement a project, this approach will result in much closer cooperation and transfer of skills than simple seminars or short visits can achieve.

Cooperation between the RC-SHP and the international IC-SHP in Hangzhou could be greatly improved. While both organisations have highly qualified directors with an understanding of the problems, the tendency seems to be to micro-manage individual projects and training sessions rather than create an environment conducive to self-sustaining SHP development in Africa. This could be facilitated through long-term exchanges between the two organisations to establish a deep understanding of the Chinese SHP development path and the extremely different political and economic landscape in Africa. While exchanges on technical aspects carried out by both organisations are generally well planned and executed, they are suitable for SHP development in a country with the resources, supply chains and experiences which China currently enjoys. The Hangzhou organisations could substitute some of these feasibility study visits with visits by officials from the Chinese Ministry of Water Resources (MWR) or Ministry of Commerce (MOFCOM) to discuss changes at a higher level of government. Arranging this sort of visit is entirely within the scope of an international organisation such as the IC-SHP.

In conclusion, visits from the Hangzhou organisations have a tendency to focus on the technical aspects of SHP, and particularly favour donation of turbines as an act of support, perhaps because it is an easily quantifiable measure of performance. However, UNIDO pointedly notes in its audits that the turbine and generator kits generally only constitute a relatively minor proportion of the costs of any given project. Even Chinese labour support for civil works is typically not required in poor African states with high unemployment. The limits of the support available through turbine donation, short visits and holding seminars would appear to have been reached some time ago, and more commitment to the soft aspects of SHP - management, policy, productive use and financing - are now required during visits by Chinese specialists. This could be achieved through longer visits with greater responsibility given to the trainers to demonstrate Chinese management characteristics, as well as visits from MWR officials and professionals from the banking sector.

Policy involvement

As has been highlighted in the previous sections, managing change at a government policy level and devolving responsibility for rural electrification projects to regional governments and utility companies are the key features of China's success in developing SHP resources. Efforts to change policy in foreign countries unfortunately go against China's official policy of non-interference in foreign affairs, and efforts to provide policy advice are hard to come across. There appears to be an expectation that the regional centres will have more success on this front.

Confused responsibility

Focusing once again on Nigeria, the RC-SHP in Abuja is currently conceived as a technical support organisation and does not have a mandate to influence government policy. Nevertheless, recently released publications by this RC include large sections by local authors on policy issues, so it can be assumed that studies carried out in Nigeria have been noticed by the relevant departments and some change may be expected in the near future. It is hoped that the older and more experienced IC-SHP will also become more involved, as despite a mandate recorded in the organisations founding principles, interviews indicated that action is far from proactive. Given the funding from the MWR rather than a more political Chinese government organ, the IC-SHP may be averse to becoming too involved in promoting the Chinese policy experience abroad. Certainly, directly training foreign officials in these aspects would need to be considerably adapted to the specific situations in the companies. The relevant periods in the history of China's SHP were carried out under a broader environment of collectivised farming communities, a communist ideology which is not present in most parts of today's world.

The IC-SHP has expressed an intention to more effectively pursue this policy avenue of its mandate by inviting delegations from target country governments. Due to the limited experience of the IC-SHP personnel in these areas, the next steps in this direction will involve developing a consultancy programme in cooperation with Chinese national policymakers focused on the specific situations and needs of developing African nations. Getting in touch with the relevant trainees could be actively assisted by UNIDO's offices in the region and take place using the facilities of the RC-SHP to keep trips for busy government officials short. Initiative needs to come from UNIDO to establish greater cooperation on contact with governments, however pending a review of the international character, ownership and funding of the IC-SHP, there is no expectation that this will happen any time soon.

It should be recognised that there are several kinds of policy interference, not all of which need to be avoided by a primarily Chinese international organisation. Providing policy consultation services for rural electrification has no direct effect on national security or sovereignty, and does not need to be a particularly visible or public activity. Coupled with ongoing technical training and partnerships with local developers, movement on this front is currently the most pressing and potentially rewarding field in which the Hangzhou organisations and China's overall policy to support SHP development could take action.

Financing and profitability

Prof. Tong Jiandong, former director of the IC-SHP, has released a book which contains invaluable information on the unique features of SHP development in China. Following policy issues, he identifies the multi-channel funding sources described above as one of the reasons behind the freedom of rural authorities to expand SHP throughout their provinces without the financing difficulties experienced in other countries[16]. Replicating these funding channels in developing countries or uncovering newly available funding sources such as the CDM mechanism is crucial to establishing momentum in the development of SHP.

While some of China's funding sources such as generous government grants may not be feasible in developing countries, there is a considerable amount of embedded knowledge and skill in the development banks of China which could be transferred to developing countries in the context of SHP capacity building. The Agriculture and Construction banks of China have particular experience here, and tailoring this to the needs and legal situations of target countries in trainings for financial sector specialists would be a highly valuable activity. The technicalities of the "electricity supports electricity" policy in place of a standard income tax are also replicable in developing countries. Finally, the Export-Import Bank of China (EXIM Bank), well known for its controversial direct funding of massive and often damaging infrastructure projects such as large hydro dams, could become involved by providing loans to SHP project or an organisation supporting SHP, resulting in considerable greening of its image. There is currently little evidence that this type of training and activity is being systematically pursued by the Hangzhou organisations.

The IC-SHP has recently collected experience on SHP development with financial support through the UNFCCC CDM mechanism (United Nations Framework Convention on Climate Change Clean Development Mechanism). Under CDM funding, a developing country implements a project which results in avoided or reduced emissions compared against non-implementation of the project. Providing financial support for such projects generates credits which developed countries may use to offset their own emissions. CDM projects are a reliable and growing source of funding for clean energy projects,

16 Tong, J. (2004). *Small Hydro Power: China's Practice*. Beijing: China WaterPower Press.

and the IC-SHP has experience in registering SHP projects for CDM funding. Training developers to exploit this mechanism is a currently untapped source of revenue in many developing countries.

The approach of UNIDO when commissioning SHP projects in developing countries also deserves some criticism at this point. Many SHP projects are artificially subsidised by UNIDO funds (or by socially aware NGOs operating in African countries), which artificially weakens the SHP industry by creating too many unprofitable projects. These "hidden subsidies" result in below-cost tariffs which can deter potential developers considering replication of a project when it arises that subsidisation will not be available every time. While each case of subsidisation must be examined on its own merits, it is generally preferable to generate a climate in which SHP may thrive rather than directly funding too many individual "demonstration" projects.

In conclusion to this brief section, there are a number of avenues which could be pursued in cooperation with developing countries to help overcome the financing problems of the local SHP developers. The best of these rely on replication of the self-sustaining policies adopted by China, however many organisations and NGOs instead focus on directly funding individual projects. While this is beneficial to the project recipients, it carries a hidden cost and is generally harmful to local industry struggling to implement profitable projects.

Fig. 14: Weir of the Tungu-Kabri project, Mbuiru, Kenya. The project was funded by the UNDP and developed by Practical Action East Africa and the Kenyan Ministry of Energy. Source: Practical Action

Technology Transfer

The HRC-SHP was the first organisation to take stock of the increasingly standardised technology involved in developing the world's largest installation base of SHP stations in China. Today, the Hangzhou organisations provide training on the design and construction of key SHP components including turbines, generators and dam/weir construction. This has been one of the most successful features of the work of these organisations, and in combination with increased effort on other fronts as described above, transfer of basic engineering technology and skills has the potential to develop strong and profitable SHP industries in developing countries.

The direct transfer of finished products such as turbines to developing countries through donations or sales needs to be viewed as a transitional measure only and not a long-term arrangement to supply and entire country or region with finished products. This approach has been used in the past to the detriment of some projects which stalled due to problems with customs or the suitability of the parts delivered. Keeping in mind that it was short and distributed supply chains which drove SHP development in China with native technol-


Fig. 15: Construction of the river diversion Dazi, near Nyanga Nation Park, Zimbabwe. The project was developed with the support of Practical Action. Source: Practical Action

ogy, the focus should be on replicating these circumstances in the developing world. The Hangzhou organisations are non-profit facilitators of change, and while helping connect purchasers with suppliers in China is helpful to their own budget, it is out of line with their own studies on sustainable industry development and should be viewed as a stopgap measure at most.

The cost of the technical components of an SHP plant constitutes a relatively minor component of the total cost, and the technology driven approach which has characterised technology transfer work from China to African states can be seen as the result of an over-reliance on engineering talent by the facilitating organisations. A greater focus needs to be placed on developing the skills to use this technology in the countries in question, as China cannot and should not provide wholesale the technology to electrify all of Africa. The Hangzhou organisations appear to be aware of this inconsistency, but this awareness has not yet developed into a coherent change of course, and the focus remains on technical cooperation. While this is certainly beneficial in its own right, it needs to be part of a larger effort to reform the entire delivery of electrification in the rural areas of countries with which the Hangzhou organisations cooperate.

Independent efforts

NGOs have been particularly active in some regions of Africa in developing SHP. Practical Action, a large UK-based NGO with a focus on actual work on the ground in cooperation with locals and local NGOs, claims to have put 1,200 micro-hydro systems in place alone. This approach obviously has some merit as well, however the same criticisms apply as to the approach of the Hangzhou organisations. There is often an excessive focus on technical support and raw provision of expertise and equipment for a single installation, rather than a focus on building a strong indigenous market with local suppliers and actual productive demand to go with the newly available supply. Many NGOs have a broader focus on general energy provision and cannot provide the specialist recommendations on policy and financing as the Hangzhou organisations could. Thus the organisations cannot be too broadly criticised for supporting SHP schemes in particularly small or needy villages, as they do no have the capacity of the larger institutions to support change at a macro level.

Many villages in rural Africa and Southeast Asia are able to make valuable use of simple SHP plants providing mechanical power or electrical power in the micro range. It is relatively simple for a locally active NGO to dispatch an minimally trained expert to a village for a short amount of time for support in developing hydro schemes built from widely available materials or scrap. This type of grassroots support sees little documentation, however the resulting installations are similar to the type of SHP in use in China in the early years. While it is unlikely that installations providing mechanical power only will catch on as broadly as was the case in China in the 1950s, where this type of mechanical energy is supported by a feasibility study, there is no reason it should not be actively promoted. A small number of NGOs are helping communities reach this goal in Africa today, however the impact on a broader scale is minimal and the main goal in this day and age will continue to be actual electrification rather than mechanical power.

NGOs can be viewed as valuable partners for on-the-ground implementation of schemes such as LURA promoted by organisations with broader authority such as the IC-SHP. Rather than implementing projects directly, the Hangzhou organisations could improve their efficiency by partnering with local NGOs for implementation, rather executing SHP projects themselves using primarily Chinese labour. However, this cooperation has not yet materialised, and due to a lack of supporting evidence it is difficult to speculate further on the results of this type of cooperation.

Summary of recommendations

- *Focus on developing SHP in rural areas where grid connection is a remote prospect unlikely to occur in the near future*
- *Devolve management and regional responsibilities for SHP development to local government to accelerate decision making processes*
- *Central governments should relinquish monopoly ownership of all of a country's electrical generation capacity to allow smaller and more sustainable generating facilities to gain a foothold in rural areas*
- *This would encourage local residents, companies and energy utilities to build, own and consume the output of new SHP plants*
- *The Hangzhou organisations should focus on transferring China's experience in finance and policy to developing countries, rather than continue the current focus on technology*
- *Cooperation at all political levels should not focus exclusively on large "friendship" style projects, but also on creating funds to benefit rural residents*
- *Regional SHP organisations should act as both pools of technical knowledge and experience for independent SHP projects and facilitate exchange with experienced Chinese officials in the financial and policy fields.*
- *International organisations should in general focus less on direct technical support and instead develop exchange programmes for foreign SHP stakeholders to learn from China's experience, and for Chinese experts to adapt their knowledge to conditions in the developing world*

Conclusion

This report has, in three sections, described in broad strokes the features and benefits of SHP for rural electrification, the state of SHP development in key regions of the developing world and gone into some detail on the practices of Chinese international organisations in promoting the Chinese path of SHP development.

SHP is a practical, simple and proven technology for the electrification of rural areas. The clear mode of electrical generation and the relatively limited impact on the environment makes SHP particularly well suited to deployment in undeveloped rural areas in Africa and Southeast Asia, and this approach has seen massive success in China where SHP power provides electricity to one in four Chinese citizens. Based on the experiences of this development path in rural China, a series of best practices have been described including management, funding, supply chain and ownership practices. Many of these Chinese practices are unique in the world, and while not all can be replicated directly, there is significant untapped potential for cooperation with the rest of the developing world.

The state of SHP development in the world today is uneven. While China is the clear leader with unprecedented existing and new developments, Europe and North America also support significant SHP infrastructure. Much of the economic potential in developed countries has already been tapped, and the industry is now focusing on efficient redevelopment of abandoned mill sites predating the broad availability of cheap thermal and nuclear plants in these countries. Developing countries, in particular those with weak national grid networks, stand to benefit most from SHP development. It is particularly viable where transport networks to supply diesel generators with fuel are weak and grid connections are a remote and unlikely prospect. Unfortunately, in the countries where SHP could have the greatest benefit, SHP development is weak due to counteractive government policy reserving all electrical generation for a government monopoly, or where insufficient momentum simply starves developers of the funds and technical expertise necessary to pursue widespread development.

The Chinese government and UNIDO support a number of institutional schemes to help developing countries replicate China's success with SHP. The most prominent of these are located in Hangzhou and focus on running regular technical training sessions for visiting foreign engineers. There are also regular but short visits by Chinese specialists to foreign countries to assist with training and feasibility studies, and longer visits where the organisations assist with project implementation directly. This focus on technical aspects, weak knowledge of the economic and broader technical situation in foreign countries and a general lack of international experience by the staff mean that much of what is taught is not practical for the real development problems in the target countries. This report has recommended long-term specialist exchanges and partnerships, the involvement of Chinese government policy makers and vendors of SHP-tailored financial packages as new goals for ongoing SHP cooperation between China and the developing world.

SHP organisations

China has actively promoted its broad experience in SHP by establishing a number of organisations and programmes to facilitate capacity building and technology exchange. The organisations are tasked with establishing industry connections for the transfer of expertise and promoting the Chinese development model for SHP abroad. Together with a number of broader international organisations and the UN, the following section lists the organisations involved with SHP today.

International Organisations

International Center on Small Hydro Power (IC-SHP)
International Network on Small Hydro Power (IN-SHP)
http://inshp.org/

The IC-SHP (国际小水电中心) was founded in 1994 with the goals of gathering together a network of members for information exchange. It became the first international organisation to be hosted in China when UNIDO began providing official support in 1999 and became the actual parent organisation in 2000. It currently receives funding from UNIDO and the Chinese Government. It operates a number of bases throughout China to distribute local expertise, and cooperates with regional sub-centres in Nigeria, India and Colombia. It manages a network of member states and professional individuals and organisations which goes under the (often synonymous) name of IN-SHP.

The organisation is tasked with promoting the exchange of information and technical assistance amongst its members, carrying out training programmes, running pilot projects, advising country governments on policy issues, and developing a global SHP industry. It also arranges country visits and helps with funding applications, but seems to provide little assistance with replicating the key to the success of the Chinese model. Beyond policy research, there is little active involvement to promote self-construction, ownership and productive use of SHP power.

Hangzhou Regional Center for Small Hydro Power (HRC-SHP)
http://www.hrcshp.org

The HRC-SHP (亚太地区小水电研究培训中心) is an organisation founded in 1981 and supported by the Chinese Government and UNDP/UNIDO with the goal of disseminating Chinese expertise in SHP around the world. It runs training sessions twice a year in French and English (recently also Russian) to educate engineers and planners from the developing world on all aspects of SHP implementation. This includes planning, feasibility studies, civil works, hydrology, operation and maintenance. It also has a wide range of industry contacts and arranges visits by Chinese specialists to rural areas to help plan new SHP projects or give lectures on SHP development. The organisation also conducts research and design activities for national hydro construction significantly larger than the "small" range – up to 300 MW. It is the parent organisation of Hangzhou Yatai (founded 2002), a SHP equipment exporter. It acts as a network of experience in design, project supervision and bidding procedures for developer partners around the world.

Regional Centre for Small Hydro Power in India (RC-SHP in India)
http://unidorc.org

Founded in 2003, the RC-SHP in India was the first UNIDO-affiliated regional centre for SHP to be established outside China. The organisation energetically hosted international meetings and managed development of several SHP installations in India, but there is little evidence available of recent activity, possibly due to funding issues. In the past, the RC-SHP has worked with the Energy Management Centre in Kerala to directly assist businesses in developing SHP and in moving towards greater energy efficiency in general. A good relationship exists with the IC-SHP, and while turbine donations took place in the past, there is some evidence of local manufacturing capacity.

Regional Centre for Small Hydro Power in Africa (RC-SHP in Africa)
http://www.unidorcabuja.org
http://unidorc.org/nigeria/

The UNIDO RC-SHP was established in Abuja, Nigeria in 2006 by UNIDO as a regional hub of the IC-SHP. Its intended purpose is to act as a centre of expertise in the SHP industry and to aid locals in developing SHP projects. The organisation is undergoing a transition and attempting to expand into a self-sufficient unit capable of providing paid consultation services.

The organisation is currently finishing an information gathering phase and has released publications describing practices for implementing SHP in Nigeria.

Centro Latinoamericano para la Pequeña Hidroeléctrica (CELAPEH)
http://www.celapeh.org

Unlike the two RC organisations, the recently founded CELAPEH (2007) is not financially supported by UNIDO. Working in close cooperation with the ESHA and with ties to the Hangzhou organisations (although several promised cooperations have yet to take place), CELAPEH demonstrates SHP feasibility in Colombia and provides consulting services in the Latin American region.

United Nations Industrial Development Organization (UNIDO)
http://www.unido.org
http://www.unido.org/index.php?id=1000763

The United Nations Industrial Development Organisation, specialised UN agency, is similar to the UNDP in having development as its primary goal. The main focus is on industrial development as a pathway to reducing poverty and meeting the MDGs, while sustainability and environmental considerations are built into every project. SHP is one of four focus areas of the UNIDO Renewable and Rural Energy programme, and the organisation has a direct interest in the IC-SHP (see below). Regional centres for SHP exist in Trivendrum (India) and Abuja (Nigeria) to disseminate expertise and provide technical assistance.

NGOs and private organisations

Global Village Energy Partnership International
http://www.gvepinternational.org

GVEP International works to reduce poverty by providing electrification in rural and peri-urban areas. They provide start-up capital for energy providing businesses and particularly promote renewable energy where possible. The organisation funds and cooperates with local partners to promote involvement in development and ownership, rather than simply providing hardware and ceasing involvement.

International Rivers
http://www.internationalrivers.org/

International Rivers is an environmental organisation focusing on activism against damaging river developments. It has several regional offices in all of the world's major catchment areas, and actively protects rivers by supporting local grassroots opposition to major hydro power developments such as China's Three Gorges Dam, Brazil's Belo Monte Dam and multiple dams along the Mekong River. The organisation promotes local involvement in decision making, particularly where large reservoirs would displace large numbers of local people and flood arable land. Instead, International Rivers promotes wind, solar, geothermal and small hydro power as more sustainable alternatives to large developments. International Rivers publishes the regular World Rivers Review, a primary source for information on developments and sharing experiences and successes

International Small-Hydro Atlas
http://www.small-hydro.com

The International Small-Hydro Atlas is an informational site containing broad profiles and facts for hundreds of countries regarding their level of SHP development and potential. The site also provides instructional reports on planning and financing SHP stations and a list of contacts sorted by country for individuals and organisations involved with SHP.

microhydropower.net
http://microhydropower.net
http://tech.groups.yahoo.com/group/microhydro/

A personal web portal maintained by Wim Jonker Klunne from the Netherlands, the main feature is the Yahoo Group which hosts an active technical discussion forum on micro level hydro power. A number of experts and equipment providers are available to provide quotes and assess individual projects on a cooperative basis.

Practical Action
http://practicalaction.org/

Practical Action is a large-scale on-location NGO based in the UK with activities around the world. They focus on reducing vulnerability and poverty through market mechanisms and promoting access to services and modern technology. Energy is a major programme for Practical Action, and they are particularly involved in promoting SHP in Kenya and East Africa, having supported numerous projects together with local NGOs such as GPower. Communication with the Africa office revealed that while local expertise is used for designing SHP projects, turbines are currently being imported from China, although there are hopes that when a critical mass of ongoing demand is established, production will become local.

Renewable Energy & Energy Efficiency Partnership
http://www.reeep.org

REEEP is a public-private partnership NGO involved with policy design and funding for renewable energy and energy efficiency purposes. They provide funding in regular cycles for replicable projects in this field, and release toolkits demonstrating the practicality and performance of past projects. REEEP also organises training sessions for national governments to help in formulating national policy to promote energy efficiency. All activities are meticulously transparent to encourage further funding, and there is a particular focus on encouraging renewable and efficiency in powerful developing countries such as China and India.

Industry Groups

Alliance for Rural Electrification
http://www.ruralelec.org/

The Alliance for Rural Electrification is a knowledge-generating organisation based in Belgium which publishes regular reports on the state of rural electrification and recommendations for technical best practices. They do not directly implement projects in the field, but provide support for partner organisations willing to do so. They particularly advocate mini grids for rural areas as an alternative to main grid extension, and promote renewables and diesel/renewable hybrid solutions as the current best practice for rural electrification.

China Association of Rural Energy Industry
http://www.carei.org.cn

CAREI (中国农村能源行业协会) is a Beijing-based organisation existing to promote the interests of rural energy developers and equipment manufacturers. It promotes sustainable development and a broader reach for energy services in rural China by acting as a bridge between its members and government policy makers. The organisation focuses on improving economic conditions in rural areas through renewable energies and improved energy efficiency. Several SHP developers are members of CAREI, and the organisation adds credibility to their studies on the feasibility of SHP as a profitable and environmentally friendly development approach when representing their projects to regional governments.

Chinese Renewable Energy Industries Association
http://www.creia.net

CREIA (中国资源综合利用协会可再生能源专业委员会) is a Beijing organisation with a focus on promoting renewable energy technology and development in China. They partner with REEEP for funding of renewable energy projects and offer support for developers applying for CDM funding. Their services include policy and legal advice for developers and a kind of marketplace to present information on foreign and domestic projects to developers looking for new projects. They strongly promote wind and solar energy, with only a limited focus on SHP, apparently due to more competent specific organisations dealing with SHP.

China Small Hydro Power Business Transactions
http://www.chinashp.com

中国小水电交易网 is a basic site focusing on providing information to SHP developers in China. The site contains limited technical briefings and information on legal procedures.

China Water
http://www.shp.com.cn

中国农村水电及电气化信息网 is an active website with regular news on developments in China's hydropower sector. Supported by the Ministry of Water Resources, there is also coverage of international cooperation and contacts to regulatory bodies, information on legal aspects, industry associations and water resource management.

European Small Hydropower Association
http://www.esha.be

ESHA is a European lobby organisation responsible for promoting the interests of the Small Hydro Power industry in Europe. Their international activities include partnerships around the world to transfer European expertise and technology in SHP.

Works cited

Davies, M. (2008). *How China delivers development assistance to Africa*. Research, University of Stellenbosch, Centre for Chinese Studies, Stellenbosch.

FOCAC. (2009). *Sharm el-Sheikh Action Plan*. Sharm el-Sheikh: FOCAC.

Hangzhou Regional (Asia-Pacific) Center for Small Hydropower. (2011). *HRC's Annual Report on Foreign Affairs in 2010 and Work Plan for 2011*. Hangzhou: HRC-SHP.

Hangzhou Regional (Asia-Pacific) Center for Small Hydropower. (2009). *Rural Hydropower and Electrification in China*. Beijing: China WaterPower Press.

Kalitsi, E. A. (2003). *Hydropower Development in Africa*. Johannesburg: NEPAD.

Khennas, S., & Barnett, A. (2000). *Best practices for sustainable development of micro hydro power in developing countries*. Rugby: Department for International Development.

Liu, H. (2011). *ICSHP and Its Activities*. Hangzhou: IC-SHP.

Loewe, P. (2010). *UNIDO Projects for the Promotion of Small Hydro Power for Productive Use*. Vienna: UNIDO.

Paish, O. (2002). *Small hydro power: technology and current status*. Renewable and Sustainable Energy Reviews , 6 (6), 537-556.

Paish, O. (2004). *Technical innovations in low head hydro*. Duffield: Derwent Hydro.

Paish, O., & Green, J. (2005). *The Pico Hydro Market in Vietnam*. Hampshire: IT Power.

Thematic Network of Small Hydro Power. (2004). *Small Hydropower Situation in the New EU Member States and Candidate Countries*. Vilnius: Lithuanian Hydropower Association.

Third Global Forum on "Hydropower for Today". (2007). *Hangzhou Declaration*. Hangzhou: HRC-SHP.

Tong, J. (2004). *Small Hydro Power: China's Practice*. Beijing: China WaterPower Press.

Tong, J. (2009). *Some Features of China's Small Hydropower*. Hydro Nepal , 4, 11-14.

UNIDO - RC-SHP. (2011). *Regional Centre's Profile*. Abuja: UNIDO - RC-SHP Nigeria.

Zhu, X. (2008). *Status Quo and Problems of Small Hydro Development in Asia-Pacific Region*. Nanjing: Hohai University Press.

The Global Environmental Institute (GEI) is a Chinese non-profit, non-governmental organization that was established in Beijing, China in 2004. Our mission is to design and implement market-based models for solving environmental problems in order to achieve development that is economically, ecologically, and socially sustainable.

The Global Environmental Institute, Suite 1-401
Building No. 5, New World Villa
Dongcheng District, Beijing 100062, China
+86-10-6708-3192

May 2011