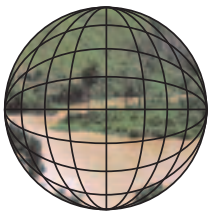

While the growth of small hydro has slowed in Europe, things look very different in Asia. The region accounts for two-thirds of the world's hydro capacity, and far from slowing down, it is enjoying robust growth. Simon Taylor, Drona Upadhyay and Maria Laguna write this review.

Flowing to the East

Small hydro in developing countries

Access to electricity is one of the keys to economic development, as it provides light, heat, and power for productive uses and communication. Today, around 1.7 billion people in developing countries do not have access to electricity, most of them living in rural areas. Despite worldwide rural electrification programmes this number is increasing, largely because these schemes are not sufficient to cope with unsustainable population growth. Despite the fact that 80% of the world's population lives in developing countries, these countries consume only 20% of global commercial energy.

According to the World Bank, the world's poor people spend more than 12% of their total income on energy, more than four times what a middle-income family in the developed world spends. Achieving the United Nations' 'Millennium Development Goals', will require significantly expanded access to energy in developing countries.

> China alone has more than half of the world's small hydro capacity and represents the bulk of installed capacity in developing countries

Accepting that energy is necessary, renewable energies must be used as a key tool in the contribution towards sustainable development in the less developed regions of the world. Small hydropower (SHP) is a renewable energy source which is suitable for rural electrification in developing countries. It is a proven technology that can be connected to the main grid, used as a stand-alone option or combined with irrigation systems. Thanks to its versatility it can significantly contribute to the electricity needs of the developing world.

The substitution of conventional sources of energy (traditional biomass for cooking, diesel generators, kerosene lamps and biomass stoves) with renewable energies like SHP can help decrease CO_2 emissions and also contribute to poverty alleviation and economic development by supplying electricity needs for lighting, water pumping and operating small workshops.

The emphasis of this article is on seeking sustainable markets for SHP in developing countries, with the implementation of schemes that consider sustainable development of the communities concerned and tapping into mechanisms that build a strong and long-term market for SHP in key developing countries. We take China as a case study as it is a country where there is currently a strong SHP market.

SHP IN THE DEVELOPING WORLD

Hydropower throughout the world currently provides 17% of our electricity from an installed capacity of some 730 GW, with another 100 GW currently under construction. This makes hydropower by far the most important renewable energy for electrical power production. In 2002 the contribution of SHP to the worldwide electrical capacity was on a similar scale to the other renewable energy sources (1%–2% of total capacity), amounting to about 47 GW. 25 GW (53%) of this capacity was in developing countries (Table 1).[1]

In the global SHP sector China is *the* major player, driven by long-standing rural electrification programmes from the government. 2005 figures, from the International Network on Small Hydropower, show SHP capacity has grown to 31,200 MW in 43,000 stations, meaning that China alone has more than half of the world's small hydro capacity and represents the bulk of installed capacity in developing countries. Growth in the Chinese SHP sector remains strong at 9% per year and there are plans to develop a further 10,000 MW in the next decade.

Other developing countries with significant SHP capacity are India (1694 MW), Brazil (859 MW), Peru (215 MW), Malaysia and Pakistan (both 107 MW), Bolivia (104 MW), Vietnam (70 MW), the

Countries in Africa have made good use of small hydro, with around 228 MW, some of it here in Rwanda MHYLAB

TABLE 1. Installed SHP capacity by world region. Source: The International Journal on Hydropower and Dams, 2004; US DOE, 2004

Region	Installed SHP Capacity	Percentage
Asia	32,641	68.0%
Africa	228	0.5%
South America	1280	2.7%
North & Central America	2929	6.1%
Europe	10,723	22.3%
Australasia-Oceania	198	0.4%
TOTAL	47,997	100%

DR Congo (65 MW), Sri Lanka (35 MW) and Papua New Guinea (20 MW), while Russia and the Central Asian states also have large amounts installed (totalling 639 MW)(2005 figures).

In the last 30 years China, Nepal, Vietnam and many South American countries have seen the development of a large number of micro- and pico-hydro projects which are providing electrification to many thousands of households. Chinese villages have developed the most micro-hydro, with 100,000 very small capacity units installed, amounting to 188.5 MW.[2] Similarly, rural families in Vietnam have installed 130,000 pico-hydro systems (usually 200 Watts) in the last 15 years on a purely commercial basis.[3] Yet although the cumulative capacity of such smaller hydro plants does not show up in the data, these projects are providing essential services to large numbers of populations in a wide range of countries and local topographies and conditions.

But despite these enormous efforts to improve energy services to rural populations through the extension of grids and the use of renewables such as SHP in the past thirty to forty years, the un-served population has not decreased significantly in absolute numbers – about 1.7 billion have yet to achieve any electrification. This amounts to roughly 400 million households, or 40% of the population of the developing countries, who remain a substantial market.

HOW SMALL IS SMALL HYDRO?

Although there is still no internationally agreed definition of 'small' hydro – the upper limit is usually taken as 10 MW (SHP definition supported by ESHA and the European Commission)

BELOW A 230 kW small hydro turbine ITPOWER **FACING PAGE** Chinese turbine workshops ITPOWER

although this rises to 25 MW and 50 MW respectively in India and China – in general SHP has minimal environmental impacts through the use of 'run of river' schemes. Also within the range of small hydro power, mini-hydro typically refers to schemes below 1 MW, micro-hydro below 100 kW and pico-hydro below 5 kW. Although all of these technologies could be regarded as small hydro power, they have specific technical characteristics that warrant their own definition. Generally speaking, micro- and pico-hydro technologies are used in developing countries to provide electricity to isolated communities where the electricity grid is not available, whereas mini-hydro tends to be grid connected. In most of the cases, no dam or reservoir storage is involved in pico-, micro- and mini-hydro schemes.

APPLICATIONS OF SHP IN DEVELOPING COUNTRIES

The World Energy Assessment estimates that between 1970 and 1990, rural electrification programmes reached about 800 million people. Most of the rural electrification programmes were achieved by extending grid connection, but a significant number of the projects in the developing world are provided by renewable energy (Table 2).

> In the past thirty to forty years, the un-served population has not decreased significantly in absolute numbers – about 17 billion have yet to achieve any electrification

Of the electrification schemes using renewables, the majority involve SHP, largely because of its suitability for powering minigrids and deployment in remote, and often mountainous, areas. It has also been used widely for grid-based power generation, and has been a mainstay of rural energy development for many years. Village-scale minigrids can serve hundreds of households in settings where there are sufficiently clustered end-users. Most village-scale minigrids have been developed in Asia on the basis of small hydro, particularly in China, Nepal, India, Vietnam and Sri Lanka where they are often also powering small industries that provide substantial local income and jobs.[4]

BENEFITS OF SHP

Using small hydro power for electrification in rural areas has many potential benefits. Apart from the environmental, health and social burdens of traditional fuels which are avoided by switching to electricity, direct economic benefits flow from the use of electricity in economically productive applications, such as irrigation, crop processing and food preservation. Employment opportunities have increased as a result of the encouragement of these productive applications and electrification has given increased potential for the development of business enterprises. For users who previously depended on traditional energy sources, the greater efficiency of electricity provides direct financial savings. At a national

TABLE 2. Renewable energy markets and typical installations in developing countries. Source: Martinot 2003

Application	Installations in developing countries market
Rural residential and community lighting, TV, radio and telephony	Over 50 million households served by small hydro village-scale minigrids
	10 million households with lighting from biogas
	Over 1.1 million households with solar PV home systems or solar lanterns
	10,000 households served by solar-wind-diesel hybrid minigrids
Rural small industry, agriculture, and other productive uses	Up to 1 million wind-driven water pumps and over 20,000 solar PV pumps
	Up to 60,000 small enterprises served by small hydro village-scale minigrids
	Thousands of communities with drinking water from solar PV-powered purifiers and pumps
Grid-based power generation	48,000 MW installed capacity producing 130,000 GWh/year (mostly small hydro and biomass, with some geothermal and wind)

level, where electricity substitutes paraffin or diesel, it is also possible that there will be foreign exchange savings on imported fuel.

INVESTMENT PATTERNS

Renewable energy is currently undergoing a shift in investment patterns – moving away from traditional government and donor sources to greater reliance on private firms – meaning that it is now more important to think about markets for renewable energy rather than simply about the technologies themselves. The old technology-oriented paradigm focused on technology demonstrations and economic viability is being replaced by a new focus on market assessment, policy and institutional issues, and demonstrations of sustainable business models. Ongoing power sector restructuring in many developing countries is opening up competitive wholesale power markets and even encouraging self-generation by end-users using smaller-scale technologies. A growing share of the power generation field is being handed to private power developers and this is affecting the prospects (both positively and negatively) for grid-connected renewable energy, where SHP is or can be a major player.

These shifts are ones that new SHP developments have to consider. As well as the shift in investment patterns, changes in national policy are also important considerations for potential developers. Countries such as India and Brazil have policies to facilitate renewable power generation, such as 'wheeling' electricity to end-users via the utility's transmission lines, from which SHP is well placed to benefit.[4] The SHP sector must also tap into local-level capabilities (as has been demonstrated in Nepal, the Philippines and Peru), involving the lower tiers of government, rural electric utilities, people's organizations, NGOs, small IPPs and most importantly, local sources of financing such as rural banks and credit co-operatives and even local entrepreneurs.

SHP POLICY FRAMEWORKS – THE CHINESE EXAMPLE

The development of good policy frameworks – for example, national policies for rural access to electricity including institutional, legal and financial frames; planning of target areas; capacity building for users and for local private sector; communication of the benefits for SHP as a sustainable tool for social and economic development – is key for the success of rural electrification by renewable sources. The history of SHP development in China is taken as an example of a number of economic and policy dimensions that have encouraged the rapid expansion of SHP technology, which could be emulated in other countries.[5] The following three factors were found to be the major contributors.

Preferential government policies

The Chinese government has given numerous preferential policies and measures to encourage SHP development. These include tax reductions, soft loans and grants, the promotion of private firms to invest in SHP stations, and policies to protect supply areas and private property.

Indigenous manufacturing capability

Since the 1970s, when SHP in China saw huge growth rates of 20% per year and there was not enough manufacturing capability to develop the required 200–300 MW total installed capacity annually, the Chinese government mandated certain counties and provinces to develop their own SHP equipment and then continued to promote local manufacturing to reduce overall costs. Local industry was eventually able to manufacture equipment for a capacity addition of more than 3000 MW per year and today China is able to satisfy its domestic needs and exports hydro equipment to other countries.

Recognizing the advantages of small hydro power over large hydropower

China has long realized that SHP has benefits that cannot be achieved through large or mega hydro stations. For example SHP construction results in fewer environmental impacts and does not require the displacement of people. In addition, SHP technology is not complex and can be easily understood and transferred to a variety of communities. Since most SHP stations have their own supply areas and local grids, they can

TABLE 3. China SHP stations by installed capacity (2001)

Type		Micro	Mini	Small	Total
Station	number	18,944	19,609	4427	43,027
	percentage	44.0%	45.6%	10.4%	100.0%
Installed capacity	MW	687	7171	18,404	26,262
	percentage	2.6%	27.3%	70.1%	100.0%
Annual output	GWh	1860	20,245	65,036	87,141
	percentage	2.1%	23.2%	74.6%	100.0%

supply electricity to local people as well as connect to larger grids. This enables these stations to maximize profits by purchasing electricity from the large grid in times of low generation and sell it back when there is excess generation capacity.

ROUND-UP OF THE SITUATION IN CHINA

China has 17% of the earth's hydropower resource and has installed over half of the world's SHP capacity (31,200 MW).The total economically viable SHP resource is estimated to exceed 70,000 MW. 90% of the number of stations and 30% of this total capacity is in the mini-hydro and micro-hydro range (Table 3).

The use of small-scale hydropower to achieve rural electrification is a major characteristic of renewable energy development in China, and was begun in the 1950s with strong central government lead. At present, there are over 600 counties (accounting for 30% of all of China's counties) that rely mainly on small-scale hydropower for electricity (serving over 300 million people) and there is a programme for rolling this out to 400 more counties.

Since 2000, the rate of commissioning of new small hydro capacity has been increasing to an average of 2000 MW per year and posting healthy annual average growth of over 7%.The country has built up such an experience in SHP that it now has a strategy of 'going-out' to other developing countries to help develop projects (usually with Chinese technology).

Financing SHP

Each year, the Chinese Government invests €30 million in the development of small-scale hydropower, attracting additional substantial investments from local governments, enterprises, and individuals to the tune of a further €10 billion. However with declining government investment in the sector, other sources are often required to bring targeted projects to development, and the Clean Development Mechanism (CDM) is one avenue that Chinese developers are now considering. The financing of hydropower in China is currently stable. The 4 major Chinese (state) banks lend to hydro projects as they are considered low risk and their loan terms are usually 3–5 years and financing negotiations take only 3 months. Some companies already have credit ratings up to fixed amount of capital which enables them to borrow up to this ceiling in one month. Meanwhile small hydro power is attractive to commercial Chinese banks, which are very active in the sector. The Ministry for Water Resources also continues to provide low interest loans for SHP development, worth about RMB300 million (€29.9 million) per year.

New renewables policy

A new 'Renewable Energy Promotion Law' was approved by the National People's Council in February 2005 which set the target of 10% of the country's electricity generation being supplied by renewables by 2020. This is ambitious given that China's GDP may quadruple in the next 15 years, perhaps requiring the total grid installed capacity to perhaps have reached 1000 GW. Nevertheless, experts have suggested that 60,000 MW of SHP capacity be developed from the yet untapped small hydro resources and certainly, with the coming into force of this law at the beginning of this year, faster SHP development can be expected.

THE CASE OF YUNNAN PROVINCE

Yunnan province in the south-west of China provides an example of an opportunity for foreign companies wanting to enter the Chinese SHP market. The province has abundant hydro power resources and an excellent track record of high annual operating hours for existing plants. The installed hydro capacity in Yunnan is currently 11,710 MW, of which 2250 MW is SHP (19%). The economically exploitable hydropower resource is very large at 97.95 GW, however the percentage of hydropower exploited is still low at 7.5%. Yunnan's hydropower targets are 18,800 MW by 2010 and 62,000 MW by 2020 (although admittedly much of this is large hydro). This is in order to strengthen the grid in the south of China and transmit power from the west to load centres in Yunnan and for export to Guangdong, which has suffered power shortages in recent years. There is only one major manufacturer of SHP equipment in Yunnan, so equipment is imported from other provinces. For SHP projects less than 25 MW, approval is handled at prefecture level, making the project process fairly straight-forward.

BELOW A small hydro plant at Tangasa in India ITPOWER **BELOW RIGHT** Small hydro plant at Sutiro in Rwanda MHYLAB

Pre-evaluation of a site in Togo, west Africa STUDIO FROSIO

SHP industry

China has a wide range of domestic SHP turbine manufacturers (about 80 in total), as well as construction companies that specialize in SHP infrastructure, and these have been supported since the early 1960s to deliver the technology to the sector. However there is still scope for technology transfer to improve performance and bring quality up to European standards, and to introduce more advanced systems – particularly in the area of automated control.

In April 2003, the Ministry of Water Resources (MWR) released guidelines for the modernization of hydropower systems in rural China, which provide further direction and standards for small hydropower development. Its overall objective is to modernize 50% rural hydropower plants by 2010, and modernize 100% of the rural hydro sector by 2015.

CONCLUSIONS

Small hydro power has already proved itself as a major contributor to electrification in developing countries with over 50 million households and 60,000 small enterprises served by small hydro at the village-level, as well as by projects feeding power into grid networks. More than anywhere, China has integrated SHP into a large percentage of the country (1000 out of 2300 'counties') and hundreds of millions rely on minigrids powered by small hydro plants. India and Brazil have also been major players in SHP and many Asian countries now have many megawatts of plant installed.

Much of this activity has taken place with the involvement of European companies already, as the EU has long occupied a leading position in the world SHP market. But with a stagnation of development within the EU, there is a renewed emphasis for EU companies that offer SHP products and services to aim at emerging opportunities in new developing countries, and at a market that has shifted in terms of investment patterns (away from donor sources to greater reliance on private firms) and power sector restructuring that is opening up competitive power markets. The SHP sector players must also consider more local-level stakeholders and local sources of financing, as a main condition for success.

Overall, SHP can help in achieving the 'Millennium Development Goals', but there are key conditions that are needed in order to succeed in SHP electrification in developing countries:

- a national institutional, legal and financial frameworks for rural electrification,
- a willingness to identify target areas and define SHP electrification programmes
- the strengthening of local technical capacities
- the establishment of a high level of expertise in the local agencies of funding institutions,
- the expansion of support for local networking between stakeholders (rural developers, bankers, institutional and private sectors, etc.)
- the development of tools for local private sector development.

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