Framework for Chinese Private Sector's Participation in Rural Hydropower

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Remarkable achievements have been scored for the development of rural hydropower and rural electrification in China. A total of 653 small hydropower (SHP)-based rural electrification counties have been completed. In recent years, numerous private investments poured into the field of rural hydropower to greatly accelerate the course of rural electrification. This article aims to focus on the general situation and background for private sector's participation in rural hydropower development in China, and the current operation system and mechanism for the joint-development of public and private sectors in rural hydropower development.

1 Management System for Rural Electrification

1) Development Mode

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

Each province, prefecture and county has their own SHP administrative entities responsible for SHP planning, design approval, construction management and other work at their respective government level. Based on the funding source and the size of the project, the listing of SHP projects is approved by the planning commission and water resources bureau respectively at the same level.

2) Management on hydropower resources

The management on water resources and the corresponding exploitation right are to be strengthened. Following the close study on the operation mechanism for the transfer of the hydropower exploitation right under the market economic conditions, it aims to set up a just, fair and open market for hydropower development.

The managing function is to be fully exerted for the water resources trades and the unified development on rural hydropower resources. The Ministry of Water Resources is in charge of guidance on hydropower trades management; and the provincial water authorities are in the position to formulate the management measures according to the local realities for exploring and utilizing rural hydropower resources.

3) Meticulous implementation

With respect to rural electrification projects, it is required to focus on the engineering quality, and to conscientiously fulfill a series of effective systems, such as the juridical person responsibility system, tendering and bidding system, engineering supervision system, and contract management system. The regulations, rules, norms and standards concerned should be followed strictly in hydropower and rural electrification development.

2 Status of Governmental and Private Shareholding in Rural Hydropower

1) System reform on investment

In late 1980s and early 1990s, the increasing private enterprises were set up swiftly, which led an serious conflict of power demand and power supply. In order to release the constraint, it was pressing to speed up the power generation. The system reform on investment in rural hydropower was therefore implemented to encourage the social sectors at all levels to join in the construction with various modes, such as shareholding system and joint-stock system, etc, so as to mitigate the shortage of fund for power development. The implementation of the policy greatly mobilized the social enthusiasm for investment in hydropower, and numerous hydropower stations were invested basing on the stock cooperative system.

2) Power construction

Before the year of 1990, the main source of the fund for rural hydropower construction was from government. After then, the private enterprises began to invest in rural hydropower. With respect to the 337 counties, the third batch of rural electrification counties completed during 1995-2000, the investment totaled 3.83 billion US$, among which, only 0.15 billion US$ from government, the rest from social investors.

Among the newly installed capacities each year, 80% are joint-stock cooperative or private stations. The details in Zhejiang Province are showed here as an example. In 2002, the total generation output from rural hydropower is 4.5 billion kWh, accounting for 18% of the total in the Province. During 1994-2000, more than 1700 rural hydropower stations were built, with a total installed capacity of 1.06 million kW. The total cost for the new stations were 1.33 billion US$, among which, 0.97 billion US$ invested by the private enterprises.

3) Power grid construction

Due to the relative complexity for the interest distribution, all funds for power grid construction are financed by the government so far.

4) Characteristics on social investors in rural hydropower

(1) Co-exist of multi-body for investment

The main developing modes are:

- Joint-development between the water resource enterprises and the electric power enterprises.
- Joint-development among the provincial investment companies, the county's investment companies and the private enterprises.
- Sole-development by the private enterprises.
- Sole-development by the foreign investors.

(2) Flexi bility for becoming a shareholder of the project

There are a variety of ways for being involved in the joint-stock system. Besides financial input, the access for land, labor force, equipment, technology and engineering construction reward are also acceptable.

In some places, the construction of hydropower station brings disadvantages for the downstream towns for using water. Therefore, the mode of using watercourse for shareholding is now in experimental stage.

3 Influence of Public and Private Cooperative System to the Current Rural Electrification

Compared with the state-owned enterprises, the private enterprises are more flexible and stress on the capital efficiency. After the private capital enters into the hydropower sector, it could have positive impact to the rural electrification.

1) Promote the development of rural hydropower industry

Due to the participation of private enterprises, the development and utilization of hydropower potential are quickened. The investment in rural hydropower started from the fewer people to the present situation that several or over tens of investors strive to exploit the one resource site.

2) Cultivate the capital managing talents

As a big amount of private capital goes to the hydropower market in the less developed area, lots of talents who are skillful in the marketing and management come into being. Some technical and managing staff flows into the private enterprises.

3) Optimize the construction management

It is quite different from the previous over-budget and engineering delay. The present cost could be reduced by 20%-30% through well-design and scientific management. The actual construction period could be shorter by 6 months or one year than the designed period.

4) Promote the industrial science progress

To reduce the cost, the private invested hydropower stations have the demand to adopt the latest science and technology, like optimized designing of the dam, the utilization of new material, introduction of automation equipment etc. Many of the private hydro power stations have been earlier to adopt the automatic control technology of "unmanned operation" or "fewer staff operation", in sharp contrast with the state-owned ones which may have nearly one hundred staff for one station with the installed capacity of only several thousand kW. The private hydropower station has the fewer operation staff and the lower managing cost, better environment, thus, the image of rural hydropower enterprise increased.

5) Meet users' demand

The electricity coverage in the rural areas increased steadily. In 1978 and 2000, the electricity coverage of township, village and household in

China increased respectively from 86.86%, 61.05% and 93.3% to 98.45%, 98.23 and 98.03%. In all 12 provinces and cities realized every village electrified. There were 2303 counties with 100% township electricity coverage, 1917 counties with 100% village electrification coverage and 1910 counties with 95% or above household electricity coverage.

The electricity reliability reached over 96%. The annual electricity utilization per capita reached or exceeded 600 kWh.

4 Present Mechanism Problems and Solutions

1) Power transmitting difficulties

Most of the rural hydropower stations just generate the electricity and the electricity must be sent to the local or state grids for distribution. The surplus energy that the local grids could not absorb in the flood seasons should be exchanged to the state grids. In some areas regulations were issued that the electricity from the rural hydropower stations be banned during the flood seasons.

2) Electricity price not normalized

The formation of the rural electricity price lacks the legalized operation. The setting and adjustment of the electricity price often depends on the experience of the decision-makers, the status of the enterprises and the understanding of the orientation in the state's policy etc. It is often not quite objective.

Some local big grids reduce the rural electricity price at will and that is not in agreement with the market supply and demand relation to achieve the same grid, the same quality and the same electricity price. The price of the rural electricity is around 2.43 Cent US$/kWh. But the price from the large grids to the small ones is usually about 4.84 Cent US$/kWh or even higher.

The big grids try to reduce the rural hydro electricity price by reasons of flood and dry season, peak and valley pricing, exceeding quota pricing, bidding pricing, wasted surplus and other names and as a result the rural hydropower enterprises suffer greatly in finance.

3) Constrains of the public welfare character

A large number of hydropower project have been built with multi-purpose services including flood prevention, irrigation, fresh water supply etc. To prevent floods and reduce the disaster, water has to be spilled in advance. To ensure the industrial, agricultural and dwellers' use of water, the rural hydropower stations often miss the chance to generate electricity so as to increase the water level against the season. Or they have to operate for long time at low head and reduced output which caused financial loss.

The exploitation of the hydropower resources should reflect the State's will and that is the incorporation of the fact that the hydropower resources belong to the State. The State should stipulate the related policy framework.

(1) Deepen the power reform

The orientation of the power reform should be: break away with the monopoly, set up the balancing mechanism, realize "dispatching neutral, power generation and grid separated, price bidding, transmission and dispatching separated and compete to supply the electric power". The power market has to be cultivated and improved with multiple legal entities and orderly competition for relatively stable supplying area and in rational electricity price.

(2) Increase the role of electricity pricing with focus on resources

It is demonstrated obviously in severe environmental pollution caused by thermal power plants. The environmental cost due to severe pollution has not been accounted into the cost and the environmental space has been used free of charge. A pricing system for sustainable development has to be established in future so as to reflect the actual value between the electricity and environment.

(3) Adopt the quota system for the renewable energy

It has to clarify and quantify the rural hydropower market quota and development objective, set a certain proportion of renewable energy in the local power construction so that the selling to the grids from the hydropower stations could be ensured and wholly sold into the grids. That is conducive to set off the unfavorable elements due to the present mechanism in the rural hydropower generation and supply.

The support to the renewable energy should be changed from the direct subsidy to the self-adjustment by the market. The adoption of the renewable energy quota will ensure legally the renewable energy like the rural hydropower fully sold to the grids.

(4) Improve the tax policy

The tax policy for the energy environment has to be worked out and issued, so as to levy the related fees due to the environmental pollution caused by the production of energy, CO_2 and other green house emissions in particular. The fee could be used for subsidizing the development of the clean renewable energy.

(5) Adopt the government management license system

The adoption of the management license system could enable the right of development of hydropower to be determined by the market mechanism, normalize the relations between the government and hydropower enterprises, and push forward the process of market-orientation of hydropower industries.

For those hydropower stations invested by the State, it is necessary to adopt the license management or entrusted management, liquidize the existing hydropower asset and increase the management efficiency, on the basis of clarifying the property and through the market competition mechanism.

It is necessary to set up the system of admission to market, encourage the rural areas to consume the green renewable energy, stimulate the ecological and environmental protection and promote the sustainable development.

(6) Stress the governmental supervision mechanism

The issues involved in the private investment in the hydropower projects such as land occupation, water price, flood prevention; ecological issues and etc are usually not to be solved by private investors. The hydropower projects involve the right to use water at both the upper and lower reaches, domestic use, power use and ecological use. All these require the government to play the executive role, consolidate guidance, normalize the management, timely supervise and coordinate the interest parties.

5 Conclusions

The continuous inflow of private capital into the rural hydropower development is an inevitable result of the structural adjustment in China's power industry. The construction of rural hydropower and electrification should be carried out in conformity with the economic, social and ecological benefit, and in combination with the social and economic sustainable development.

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HRC's expert attended the 4th World Water Forum

As one of the members of the Chinese delegation, Mr. Li Zhiwu, Vice Division Chief of International Cooperation, Science and Technology, HRC, attended the 4th World Water Forum, which was held in Mexico City from 16th to 22nd March 2006, with the theme of "local actions for a global challenge." More than 11000 representatives from over 80 countries, including China, participated this main international event on water, which comprised the following contents: the Thematic Forum, the Ministerial Meeting, the Youth Water Forum, the Children Water Forum, the Water Expo and the Water Fair. Representatives at the gathering discussed widely on the issues concerned, such as the further actions for effective saving, protection, management and utilization of water resource, and the integration of regional actions and world water conservancy construction, etc. ■

Environmental Integration of Small Hydropower Development

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Abstract: *On the basis of cooperative research with European professionals, problems relating to environmental and ecological protection were discussed while small hydropower development in China currently was introduced in this paper. Guidelines of small hydropower development dealing with environmental protection were suggested hereby. Various specific technical environmental solutions focusing on small hydropower development applied in European and other developed countries were also introduced in this paper. Main environmental solutions are discussed as follows: integrated design should be advocated during plan/design stage; eco-hydraulic engineering and its utilization in SHP design and construction; effective technical approaches to relieve and eliminate the impact of river interception and fix the reasonable minimum biological flow; environment-friendly mitigation and compensation measures for high/low-head hydropower schemes applied in diversion works, intake, nature-like fish-passes, penstock and powerhouse design; study and application of the new technology, material and equipments; launching renovation of environmental protection in existing stations; emphasizing public participation and their acceptability for the SHP environment; coordinated inter-disciplinary study at national level. etc. Two case studies in Sweden and Australia are given here.*

Keywords: *Small hydropower, Hydropower potential with environmental constraints, Entironment, Environmental integration, Integrated design, Minimum biological flow, Nature-like fish-passes, Solution, European, China, Case study*

1 Preface

Small hydropower (SHP) is considered as renewable and green energy. Compared with thermal power and large hydropower, SHP has more ecological benefits and less negative effect on environment. Although SHP has less ecological problems, the fact of recent decades is that SHP didn’t advanced harmoniously with environmental protection. The goal of environmental integration is out of our sight, which is worthy of our overall survey and study.

2 SHP in the World

Although there is still no international consensus on definition of ‘small’ hydro – the upper limit is usually taken as 10 MW (SHP definition supported by ESHA and the European Commission) 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 hydropower, 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 hydropower, 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.

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 2-1).

In the global SHP sector, China is the major player driven by long-standing rural electrification programmes from the government. 2005 figures 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 16,000 MW in the new Five-Year Program period (2006-2010).

Table 2-1. Installed SHP Capacity by World Region

Region	Installed SHP Capacity(MW)	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%**

Source: The International Journal on Hydropower and Dams, 2004; US DOE, 2004

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 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).

3 Environmental and Ecological Protection Impact on SHP Development

3.2 China's Current Situation

China has witnessed a swift SHP development in recent years. Total installed capacity have reached 34.66GW with 2 million kW to 3 million kW of annually new-added installed capacity, accounting for more than 30% of the hydropower and 6%-7% of power industry of China, ranking the first place in the world. In the progress of large-scale and rapid development appeared something adverse, especially the SHP exploitation's impact on the ecological and environmental protection, to which more and more attentions have been given. A trendy action of "Seizing river section", which implies an illegal movement of exploitation of SHP resources in some rivers without comprehensive survey and authorization, has resulted in out-of-order exploitation, such as interruption river, water-quality deterioration and the damage of landscape. In some regions, river health and ecology balance have been badly disturbed due to over-exploitation without taking ecological water utilization into consideration. *Nanxi River, a national important scenic spot, is an example for such case. The out-of-order SHP exploitation led to river flow interruption, water-quality deterioration from level 1 to level 5 and difficulty of supplying domestic-water to a number of counties. A special local aquatic product XIANG fish, almost reaches extinction. It is reported that in 2003, more than 90 SHP stations was being exploited or under construction in the upper reaches. Construction muck without appropriate treatment was flushed down by flood, which resulted in the riverbed rising of the lower reaches in the key scenic spot, and deepwater pond was shallowed.*

Local governments, generally responsible for financing environmental protection and reservoir management of medium and small hydro project, are often confronted with local fund shortage. They would usually cut down local investment or joint investment with private companies. Some local governments even sacrifice environment and resettled peoples' profits to make invitation for business and investment. Furthermore, there is no strict supervision of project construction from local related sector who would usually yield to the inappropriate decision of individual local leader. For designers, good and the bad mixed together, and out-of-order competition occurs in SHP design, as result of which, some designers sacrifice designing quality to cater to some owners' incorrect requirement.

A batch of "4-withouts" illegal stations were built, i.e., without approval, design, acceptance test or normal management in some areas, which leads to a serious result and damage of environment and ecology. It is harmful for SHP sustainable development. Under impact of negative influence, people now realize that we must attach importance to the environmental protection during SHP development. Emergent measures had taken by the government to weed out nearly 3,000 illegal stations in 2004. The practice of exploiting SHP orderly and protecting environment has kicked off.

On 25 June 2004, Ministry of Water Resources issued "*Notification on further strengthening the work of rural hydropower*" (No.214, 2004) in which strengthening management of water resources, standardizing hydropower market ,rigorously reinforcing basic construction program and management of rural hydropower construction are prescribed confirmatively. "*Urgent notification on stopping the out-of-order construction of power stations*" issued on November 24, 2004 by the State Council via the State Development Reform Commission is the severest and timely shock for the out-of-order construction of SHP stations.

In respect of the environmental protection in the hydropower station construction, optimization of the stations' operation and management and mitigation of impact of the water environment and aquatic ecology, "*Notification on strengthening environmental protection in hydro-*

power construction" issued by the State Environmental Protection Administration and the State Development & Reform Commission on 20 January 2005 pointed out, "*the hydropower station construction must follow the environmental requirement of the law of environmental impact assessment and regulations of the environmental protection for construction project, strictly execute the regulations of the environmental impact assessment, and seriously carry out environmental protection design. We must reduce hydropower negative impact on environment as significantly as possible, especially fulfilling the environmental protection measures such as: protecting low-temperature water, fish, flora and fauna and especially on aquatic ecosystems, maintaining water and soil in the progress of construction, doing well work of resettlement* ". We must study and formulate optimum operation mode and mitigate SHP adverse impact on the water environment according to the requirement of power and water supply and ecological environment. For constructing diversion-type station or other types, we must avoid flow interruption in part of the river resulting from hydro power station's operation. It is necessary to set down the construction and operation of the water release structure to make sure amount of ecological flow.We must put economical,social ecological benefit together to fix ecological flow on the basis of the need of local production,living,ecology,and landscape. For the station built on the river with navigation in the lower reaches,it is necessary to meet the flow demand for river navigation whereas devices for protecting fish and other aquatic should be able to work normally.

"*Rivers, watersheds and aquatic ecosystemsare are the biological engines of the planet.They are the basis for life and the livelihoods of local communities. Dams transform landscapes and create risks of irreversible impacts. Understanding, protecting and restoring ecosystems at river basin level is essential to foster equitable human development and the welfare of all species. Options assessment and decision-making around river development prioritises the avoidance of impacts, followed by the minimisation and mitigation of harm to the health and integrity of the river system. Avoiding impacts through good site selection and project design is a priority. Releasing tailormade environmental flows can help maintain downstream ecosystems and the communities that depend on them*".[2]

A minimum environmental flow (or reserved flow) downstream of hydroelectric installations emphasizes the protection of the natural life in the river.

In recent years, power shortage drives many local governments to construct unqualified and unauthorized SHP stations as insanely as a man drinks water with poison to quench thirst. Environmental protection and ecological constraints therefore seem not serious. It can be anticipated, with the normalization of power supply and demand, and building of a well-off society in an all round way and continuous raise of ecological protection idea from communities and society, similar to the large hydro power, and similar to the developed countries, ecological constraints on SHP development will increasingly be salient, SHP would witness a healthy progress if ecological protection is correctly set down. Vice versa, the SHP sustainable development would be frustrated. So it is necessary to study and formulate relating strategy as early as possible.

The recent ecological protection program of "replacing firewood with SHP" has been playing active role in the forest protection and reducing the emission of greenhouse gas. Lots of demonstration and practice of the project's ecological benefit have emerged. There are still few research results relating to the environment and ecological study of SHP except that same method of monetization account of mitigation of environmental pollution and ecological destruction from the replacement of firewood by SHP has set to study in the academic circle recently. These results would likely be conducive to promoting the sustainable development of SHP.

Lots of systemic studies of the SHP impact on environment and ecology have been performed in developed countries where many new technologies and measures have been adopted in addition to strict execution of policies and programs of authorization. It is practically proved that these new technologies and measures are basically suitable for Chinese case because it is most probable for them to relieve the SHP negative impact on local environment.

3.2 China's Guideline of SHP Development

Scientific development concept and the idea of human's harmonious coexistence with the nature and constructing the society friendly with environment, as initiated by Chinese government, are taken as the guideline for resolving the problems of the environmental and ecological protection of SHP development.

In the early stage of planning,

we must formulate and put into practice the new idea of the resources of environmental protection and exploitability, setting the plan on the basis of sustainable development integrated with environment at the very beginning. We must carry out environmental assessment paralleled with other works rather than deal with environmental protection after completion of design. All above mentioned means that measures for prevention and mitigation of the environmental impact should be integrated in the process of plan and design.

To realize the objective of "***exploiting under protection and protecting during exploitation***" and stick to the integration of the hydropower exploitation and ecological environment, we must create the SHP system friendly with ecology and environment, consciously coordinate the requirement of economy and environmental protection, and study new methods for the sensitivity of local community to environmental problems and new approaches for broaden involvement of the public to reach a win-win objective of both economy and environment for the selected option.

4 Environmental Integration Solutions

4.1 Emphasis should be given to the combination of SHP and environment, with the environmental impact assessment carrying out simultaneously during plan/design stage, not successively

4.1.1 Integrated design

Integrated design should be advocated. Presently, the design method is: to make sure the realization of maximum power production, and followed the amendment for meeting the requirement of environmental protection. However, environmental constraint could actually impose bad effect on the general design and layout of a SHP station. Integrated design will prevent designers from considering that respect of the environment is just a burden. Mitigation and compensation measures, which presuppose a negative impact, should be replaced by a design process where environment is considered as an important element. Integrated design can reduce the project's adverse impact on the landscape. The prevailing review procedure of SHP design and relevant standards for environmental protection should also be addressed and modified accordingly.

4.1.2 Ecological engineering

We should strengthen theoretical study of the eco-hydraulic engineering and its utilization in SHP design and construction, such as planting vegetation, naturalizing dam, consolidating the bank and constructing auxiliary hydraulic buildings. Mechanical and scenic impact could be mitigated consequently.

4.1.3 River Interception and water intake's impact on environment

For diversion-type hydropower stations, water is drawn into the powerhouse though entrance channel, and the natural flow was reduced and ecological system changed due to the new-building obstruction such as dam and intake structure. It is necessary to study effective technical approaches to relieve and eliminate the impact of river interception and fix the reasonable minimum biological flow as well as the degree of pollution of downstream water quality derived from the hydropower station construction. We should develop the simple and quick assessment method on the basis of quick test non-biological index to serve such kind of impact.

4.1.4 Civil engineering works

4.1.4.1 Waterways (Diversion works, intake and fish passes)

1) It is necessary to take the environmental integration into decision of the intake structure's height besides the hydraulic condition and the requirement of power generation. From an environmental viewpoint, the height of intake structure is the most important factor and similar to all other civil works which is mostly site-specific, enjoys ***no universal design***. With few exceptions, diversion works and intakes interrupt river continuity to an extent essentially proportional to the efficiency of the fish pass. ***Integrated design*** would reduce the visual impact of civil engineering works on the environment.

A set of rather new solutions is used to reduce environmental impact in high-head hydropower schemes:

• Hillside-channels and steel open-air penstocks on the headrace side replaced by ***underground plastic penstock*** (glass reinforced plastics, High Density Poly Ethylene, HDPE) to reduce land occupation, visual impact and maintenance.

Fig 4-1. An uncovered anchoring block at penstock without expansion joints

•When the head is too high for this solution, ***maintenance-free penstocks*** which are devoid of expansion joints, should be preferred, as it is thus not necessary to build tracks, roads or inclines planes to reach them.

• Completely ***accessible***, uncovered ***anchoring blocks*** can also reduce the impact of penstock civil-engineering works and increase safety.

Because of their large dimensions and discharges, environment-friendly solutions for low-head waterways are difficult to design. However, important mitigation and compensation measures to reduce environmental impact begin to be taken, such as:

• Reduce of height of ancillary work, such as the hydraulic cylinders which move gates located in the body of the weir to reduce the visual impact.

• Design of headrace and tailrace channels, which serve ecological functions (that of a biotope).

• Creation of structured embankments in semi-aquatic areas.

• Use of bioengineering in terrace, banks and splash zones.

2) Sonar and optical devices can keep the fish away from the abstraction pipe. These devices may apply in special intake such as bottom intake and screen, to attract fish and prevent fish from entering plant waterways to reduce the environmental impact of SHP.

3) Diverse fish friendly by-pass systems (concrete fish ladders, rock ramps, Bordland lift, pool and step design-nature-like or not-…)and ***device to attract fish*** to the passes are now available and installed.

More and more ***nature-like fish-passes*** in Europe have been revealed themselves as being efficient. In Germany, a special device has been developed for facilitating the downstream migration of eels. Small artificial waterways with step and pool morphology replacing the fish ladders using traditional technology and structure is a trend. Such kind of artificial waterways appears mostly in small mountain rivers. They have the following functions, for most of the fish species or for the aimed species:

Fig 4-3. A powerhouse coated with local stone

• They allow beside ***upstream migration also downstream migration,***

• They create spawning grounds and biotopes,

• They serve as a habitat for young fish.

Fig 4-2. An excellent example of fish friendly *nature-like fish way* with step and pool morphology[12]

Highly site-specific, as are all civil engineering works, ***no universal design*** exists for fish passes. Until now, there is however no any kind of standardized, efficient and low-cost design of fish immigration device for SHP.

4.1.4.2 Powerhouse

To look beautiful and visual comfortable, at least acceptable, from the outside, the station's walls should be made of local material as much as possible for the purpose of harmony with environment. The stations would be easily accepted as an important resource of the renewable power, if looks like local village in mountain areas. The Oriental is likely to share great difference with the Occidental in respect of the design thought about the harmonization between buildings and its surrounding and acceptability.

4.2 Study and application of the new technology, material and equipments

1) Studying the new material of dam. For example, in Japan, a new technology of building dam with gelatinization gravel is under way, through which free-muck disposal during the construction could be realized.

2) Adopting the air cushion surge chamber for protecting vegetations .Norway is adopted at this kind of technology.

3) Simple and quickly-built powerhouse, underground powerhouse, etc. for an instance, La Douve second stage hydropower station in which turbine is driven by the sewage water from the outlet tunnel of the sewage water treatment station in the Alps was installed in only 23 minutes with the help of helicopter due to no way to the site after several month's making and assembly in workshop including powerhouse, the panels of control, service power and electrical equipments. The underground powerhouse can easily emerge with environment (low noise), though high cost.

Fig 4-4. The La Douve II hydropower plant uses the effluent of a wastewater treatment station in the Swiss Alps. Its Pelton turbine develops 75kW[8]

4) Improvement of electro-mechanical equipment

• Studying on the technology of substituting Bio-degradable oil for lubricating oil to prevent leakage oil's pollution to the downstream water. GE Hydropower Company, to reduce the risk of oil pollution of SHP, have developed the technology of reducing and even canceling lubricating oil in the hub of the Kaplan turbine's runner, and adopted the Kaplan runner without oil lubrication. The first commercial unit utilizing technology of no oil lubrication was installed and put into operation in Sweden in October 2000, and up to now it have been working very well. The second, third, fourth and fifth commercial unit were installed and put into work respectively in August, 2002 and autumn of 2003. There are also such kind of commercial units running well in Finland. Many orders for such kinds units have been procured in Europe.

• Designing of the fish-friendly ecological type turbine runner.

• Adopting low noise gearbox and generator.

For example , the ***Powerformer***, initiated by ABB-ALSTOM in Sweden, is a new type of generator in which there are no high-voltage switch box and transformer. Stator coil is made up of high-voltage cable with the output voltage equivalent to the transmission voltage, which lead to the lower cost of equipments and construction as well as the less environmental impact derived from construction of the step-up switch-box station. ***Powerformer***, also suitable for the smaller hydropower station, has been put into commercial use in SHP station with installed capacity of 5 to 10MW. With higher efficiency of 0.5% than a set of conventional generator plus transformer, ***Powerformer*** enjoys less cost of operation and maintenance.

In addition, the compact generator could be installed by developing small bulb turbine and utilizing ***PME (Permanent magnet excitation synchronous generator***) in case of the turbine maker's lining up with the generator maker.

• Oil-free governor, assembled electrical panel and automatic trash-rack, etc..

5) Spreading the unmanned power station and containerized SHP station. For instance, the powerhouses of some SHP stations in Australia all look like containers with small area covering and compact configuration. Small space serving for aisle is left besides equipments. And there is no crane in the powerhouse. Its roof could be opened in case of unit maintenance with the truck crane. You cannot see any windows in the walls, and a fan is fixed on the roof used for ventilation.

The unmanned SHP stations prevailing in the developed countries give rise to the different powerhouse design:

• No emphasis on upright wall with quaint shape.

• In spite of loud noise inside, no lower than in Chinese SHP stations, noise, well confined to the fully-enclosed powerhouse without windows, cannot be heard outside, which meets the demand for environmental noise. Therefore you cannot know where the station is located, as some of its steel penstock and tail water are invisible, even standing in front of the station's gate. On entering the powerhouse, you can find a small device fixed on the wall, a pair of exquisitely packed cotton balls used for earplug would appear if you press on it.

• No auxiliary powerhouse and other structures but a quaint-shaped powerhouse erecting on the ground.

•No particular ventilating equipment. Horizontal generator adopts the fully-enclosed ventilation, thoroughly different from those of China, all of which use exposed ventilation.

Lots of concerns are given to the environmental protection in SHP exploitation in the developed countries where as little as possible areas are covered in order to preserve vegetations. Different measures have been adopted in accordance with different areas, which fully show the characteristics of combination of SHP and environment.

4.3 Hydropower construction

The measures of the environmental protection in hydropower station construction mainly include:

1) The "3-simultaneousness" during construction requires that engineering construction together with environmental protection, facilities for water conservation and ecology and environment's construction should be put into operation simultaneously. In addition, vegetation should be restored and ecological garden in the dam area be built.

2) Controlling soil erosion, no emission of wastewater, keeping good water-quality of the river.

3) Adopting good construction road and special enclosed garbage way and vessel of loose concrete for prevention of air pollution.

4) Choosing appropriate construction measures and time (for closure of dam gate) to resolve the ecological and environmental problems such as flow control and lower reaches' demand for the water.

"*The Guideline and Regulation of the Environmental Protection in the Rural Hydropower Project Construction*" have been drawn up and examined but not yet issued officially in China. The content about environmental protection in construction mainly includes: the prevention of three kinds of muck (sewage water, waste gas and solid muck) and noise pollution, noise control, ecological protection, human health protection, management and monitoring of the construction environment.

4.4 Launching renovation of environmental protection in existing stations

We should carry out renovation of environmental protection in existing stations, such as improving old runners with technology of dry lubrication. The existing stations are already part of the environments, it is inevitable that realizing station's modernization would certainly involve research, development and demonstration and the electro-mechanical devices. These measures will mitigate environmental impacts and reduce cost of SHP.

4.5 Emphasizing public participation and their acceptability for the SHP environment

The environmental integration of SHP can be improved by technical and non-technical measures with the latter as main one. It is better to adopt the multi-purpose SHP project combining flood control, irrigation, water supply and power production, in order to improve the social and environmental acceptability for the SHP stations especially for the new ones. The priority of exploitation should be given to the new standardized method for monitoring the public sensitivity for the environmental problems and new option which can realize wider public participation in the designing progress.

4.6 The coordinated inter-disciplinary study at national level

China is a large SHP country but far away from strong one, especially regarding SHP technology study. It is necessary for the SHP development to launch inter-disciplinary coordination. Some technologies developed in other power fields can fully be applied the SHP sector. For instance, the low-speed AC generator which used in wind power is also used for the low-head Bulb turbine by some large Companies. Therefore, it is important to support SHP's cooperation and exchange of information and special knowledge with other fields such as wind power, especially in respect of the electro-mechanical equipment, control and monitoring technology for prevention of waste and repetition of the academic resources. Currently, China seems still has no definite master plan for technology development and its capability of scientific research is also weak. These should bring attention to the decision maker.

5 Summary

Hydropower is a renewable energy, improvement of environment protection deals with a better integration of the SHP plants to the local ecosystem. Such integration mainly relates with noise reduction and reduction of the impacts on fauna and flora and especially fishes. This infers that:

• waterways (pipes, penstock, channels) and their setting and maintenance do not impact on the local ecosystem, by using under ground or/and maintenance-free, ….

• water stream continuity is not broken, by letting an appropriate residual discharge within the stream and by setting efficient fish passes, so that notably fish upstream and downstream migration should not be disturbed.

• fish are not damaged within the turbines: either systems are set to prevent them from entering the turbine, either the turbine has a special fish-friendly design.

• the whole SHP equipment integrates the landscape notably on a visual point of view by using bioengineering techniques for example.

Such improvements could be helped by establishing general guidelines, so as to design from the beginning the power plant as a whole with a focus on environment integration, and find the best environmental, technical and economic solutions. Moreover standard and objective methods for environmental assessment would gain at being developed so that every one concerned by a SHP project (investors, officers, environment associations, …) could base their analysis on an official study.

And finally, techniques and procedures for SHP integration to the environment need to be promoted and disseminated in order to improve local public awareness, to prevent problems that could spoil SHP picture.

SHP integration to the environment is essential when dealing with SHP picture as a renewable energy.

Table 5-1. SHP Environmental Impacts and Feasible Solution (Suggested by ESHA[10])

SHP Impacts	Feasible Solutions
Landscape – visual intrusion	Painting the water intake pipe
	Embedding the water intake pipe in a "geotextile"
	Burying the water intake pipe
	Integrate the powerhouse in the landscape by using local materials and architecture
	Underground works for outdoors power station and transmission line connecting the plant to the grid
	Disturbed ground can be replanted with appropriate vegetation
Water resources, including impacts on other water uses	Maintaining an appropriate minimum reserve flow
	Design and construction techniques to maintain or replace local drainage channels
	Retention or detention structures to avoid increase of runoff
Flora and fauna, and especially on aquatic ecosystems	Fish passes
	Installing grids or other diversion methods across water intakes and tailraces to prevent the entry of fish into the turbine
River water quality	Clearing of biomass
	Installation of multilevel water intake pipes
	Re-aeration of deeper waters and
	Aspiration turbines
	Sluice gates that can be opened and closed, pumping sediments slurries over the dam crest or removing sediments from the river by conventional dredging or pumping out the slurry elsewhere
Other impacts	Noise can be minimized by proper noise abatement measures or underground works

Fig 6-2. Weir of Nykvarn MHP

Fig 6-3. Intake of Nykvarn MHP

Fig 6-4. A 325 kW turbine manufactured in 1942 still kept in operation

Fig 6-5. The ancient KindaCanal nearby

6 Case Study

Case study1: Nykvarn Micro Hydro Power Station, Sweden

Fig6-1. Nykvarn Micro Hydro Power in Linkoping, Sweden(325kW), an excellent example of environmental friendly SHP. A trash-rack cleaner is individually designed by the plant self

Description of the system

Nykvarn is a mini-hydropower station located in Linkoping, Sweden with capacity of 325 kW, a fall height of 2.8m and 1.5GWh annual production. Extension torrent of water is 16 m^3/s, middle torrent of water is 15m^3/s. The station was built in 1942. Its generator, turbine and gearbox are from that year. Electrical, control and hydraulic equipment are from 1997. The trash-rack is from 2001, and it's without hydraulic fluid, and engines controls with frequency controllers, instead of hydraulic engine.

Environmental measures

Like most of SHP plants in Europe, Nykvarn has been in operation more than 60 years. But it still function well. The environmental integration (its powerhouse, intake, trash-rack cleaner and weir etc.) of the whole plants is a typical example for that kind of environment-oriented renovation of existing plants in many European countries. The old high quality electromechanical equipments and powerhouse combined with refurbishment modern control and monitoring system is so harmonious and historical. The existing environmental friendly plant is already part of the whole environments including the ancient Kinda Canal, office buildings and factory nearby.

Case study 2: Parangana Dam SHP Station, Australia

Fig.6-6 Parangana Dam SHP plant(1×750kW), a containerized SHP station in Tasmania State, Australia

Description of the system

With a set of vertical-shaft Francis turbine of 750kW, the inlet penstock layouts in line with the tail-water canal, over which a metal container is built as the powerhouse covering $8m^2$. The oil pressure device, along with the switchgear equipment, is located in the auxiliary room that is higher than the powerhouse and faces the containerized substation. Its parameters are:

• Net head: 36m

• Discharge: 1.05-2.7L/s

• Output of generator: 750kW

• Type of the turbine: Francis turbine with speed of 750 rpm.

• Type of the generator: Asynchronous generator

Environmental measures

The specific design lies in the installation method of this plant. The powerhouse, a metal container, is directly erected on the tail water canal which is connected with the inlet penstock tunnel.

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Climate Change in Scotland: Impact on Mini-Hydro

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ABSTRACT

UK Government targets for renewable energy and the new Renewable Obligations suggest a renewed interest in mini-hydropower. However, changes in climate and, in particular precipitation, have been shown to significantly alter the quantity and distribution of river flows. Furthermore, these changes have been shown to impact on the production and, consequently, the economics of large hydropower schemes. The literature highlights that the sensitivity of roduction to changes in climate increases significantly as the amount of storage declines. Given that run-of-river mini-hydropower schemes have little or no storage they may be particularly vulnerable to the changes in river flow quantity and distribution that result from climate change. To assess the threat, a simple software model has been developed that enables an examination of the sensitivity of mini-hydro production and economics to climate change. A possible low-head scheme located in the Scottish Borders is used as a case study. The impact of altered precipitation and temperature on river flows, production and project economics are examined. Consideration is also given to the potential and desirability for making the project more climatically robust.

INTRODUCTION

To assist the United Kingdom (UK) to meet its obligations under the Kyoto Protocol and further reducing carbon dioxide (CO_2) emissions by 20% by 2010, the Governments has set targets for renewable energy generation. Under the Renewables Obligations (DTI, 2002; Scottish Executive, 2002a), electricity suppliers must ensure that 10% of the energy they provide to consumers in England and Wales (18% in Scotland) is derived from renewable resources. With existing large hydro explicitly excluded and new build unlikely, the energy must be generated from wind, wave, biomass or small- or mini-hydro plant. Production from these resources will be accompanied by Renewable Obligation Certificates (ROCs) which may be sold by generators to suppliers. The obligation encourages renewable developments as suppliers failing to purchase sufficient ROCs will be liable for buy-out penalties. This revenue earned from ROC sales significantly improves the economics of renewable resources particularly for mature technologies like hydro (Harrison, 2005).

While the 2010 renewables target is quite modest, the targets for later years are expected to be more significant: the UK has aspirations for 20% of demand by 2020 while the Scottish Executive is currently proposing a target of 40% (Scottish Executive, 2002b). Such targets will require the exploitation of much of the UK's renewable potential. In Scotland, the unconstrained potential has been estimated at around 59 GW of which some 300 MW is small hydro potential capable of producing energy at less than 7p/kWh (Garrad Hassan, 2001). Although many of the better sites for small and mini-hydro have already been developed and that other renewable technologies are or will become cheaper, there is still scope for development in Scotland and elsewhere.

While the Government's response to climate change may promote the development of small- and mini-hydro, the effects of climate change itself may not be in the best interests of this technology.

CLIMATE CHANGE AND MINI-HYDRO

A large and increasing body of work has highlighted the potential for predicted changes in climate and, in particular precipitation, to significantly alter the quantity and distribution of river flows (e.g. Arnell, 1996). Furthermore, these changes have been shown to impact on the production and, consequently, the economics of large hydropower schemes (Harrison and Whittington, 2002). The literature also indicates that the sensitivity of production to changes in climate increases significantly as the amount of storage declines. By definition, run-of-river (RoR) mini-hydropower schemes have little or no storage. Furthermore, they are designed from flow duration curves where there is a trade-off between harvesting high flows and remaining operational during low flows. Given that installations have normally only one turbine, the capability of mini-hydro to respond to changes in flow distribution is rather limited. These factors may lead mini-hydropower to be particularly vulnerable to the changes in river flow quantity and distribution that result from climate change.

The capacity and potential returns from mini-hydro schemes means that they have been largely neglected by largescale developers and their construction has been predominately undertaken by smaller companies or individuals. With often only one plant in their portfolio, the failure of that plant, either physically or in terms of lower than expected revenue, has the potential to create great hardship or even insolvency for the investors. Hence, the lack of significant financial support makes the consequences of detrimental climate change perhaps more severe for smaller plant.

Despite the apparent sensitivity of mini-hydro to climate change it has largely been neglected in studies. This is partly because analysis has tended to concentrate on large-scale hydro in regionally or nationally significant river basins, presumably because impacts would initially appear to have the greatest impact. It is also because, when compared to the output of large-scale thermal and large hydro plant, the contribution of small-scale plant could be considered negligible. With the general trend towards smaller, geographically distributed renewable generation the contribution of small-scale plant will, in the future, no longer be considered negligible. As such it is important to determine the scale of the changes that global warming may bring and their impact on mini-hydro. In carrying out this exercise, particular attention has been given to the differing needs and issues of small hydro developments. The feasibility budgets of mini-hydro schemes means that extensive hydrological studies of climate change is unlikely to be possible. The aim here is to examine what may be achieved using techniques and ideas available to all would be mini-hydro developers.

SCOTTISH BORDERS CASE STUDY

The potential mini-hydro scheme chosen is at Ormiston Mill on the River Teviot in the Scottish Borders (Figure 1). The potential of the site is identified in the Salford (1989) study of UK small hydro potential, which recommends a 240 kW machine operating on a 2m head to produce around 1,200 MWh annually. At present the weir has been partially removed (and lowered) although some of the original construction is evident near the entrance to the old mill lade which is also obscured and partially filled. The original sluice gates exist but are in a poor state of repair.

Figure 1. Case study catchment

The scheme is modelled in a spreadsheet version of software developed by Harrison and Whittington (2002) and has been simplified for use with run-of-river hydro schemes. It uses a monthly time step, in-line with the most readily available climate data. The model consists of several serially-connected components: a catchment model that converts climate time-series to estimates of river flows, and a run-of-river hydropower model that provides estimates of production, revenue and economic performance. The model was driven by a thirty year time series of climatic data covering the years 1961 to 1990 acquired from the National River Flow Archive at CEH Wallingford (NRFA, 2004). The data requirements include precipitation and temperature together with several others required for the calculation of potential evapotranspiration (PET). The model performs well although it has a tendency to overstate winter and spring flows.

The hydro scheme is modelled in a very simple manner with net head, crossflow turbine efficiencies, river flows and hence production assumed to be constant over each period. Turbine maximum and minimum flow limits are applied along with the requirement to provide compensation flow. For illustration, the plant capital costs were taken to be £1200/kW installed and the annual operations and maintenance cost is 3% of capital cost. Revenue is calculated on the basis of a flat rate payment of £60/MWh which includes both energy and the ROC. The key project performance parameters are given in Table 1.

Table 1. Key project parameters

Project Parameter	Value
Catchment area	1,110 km^2
Mean annual rainfall (1961-1990)	939 mm
Mean flow (1961 to 1990)	19.8 m^3/s
Mean monthly production	125 MWh
Payback period	7 years
Intenal Rate of Return(IRR)	12.9%

CLIMATE SENSITIVITY

The simplest means of analysing the effect of climate change is to perform a sensitivity analysis. This involves uniformly altering precipitation and temperature time series across a range of changes and examining the outcomes for river flows, production and financial performance. Generally, one would want this range to encompass the extent of possible changes in climate that may occur. On a global scale we can expect a temperature rise of up to 5.8°C by the end of the century (IPCC, 2001). More locally, by 2080, this area of Scotland may experience annual mean temperatures that are 2.5 to 3.0°C higher than the 1961-1990 mean, while annual precipitation may increase by around 20% (Hulme et al, 2001). As such, increasing mean monthly temperatures by up to 4°C and altering precipitation by up to 20% will give an indication of how the Teviot catchment and a hydro scheme built at Ormiston Mill would respond to changes in climate over this century.

As would be expected, increased precipitation raises mean river flows whilst higher temperatures tend to lower flows. The effect of uniformly changing temperatures is limited to just over 0.6%/°C, while changes in precipitation lead to flow changes that are proportionately greater than the incident change in rainfall, an occurrence noted in many climate impact studies (Arnell, 1996). A 20% rise in precipitation coupled with a 4°C rise in temperature (defined as 'wet' conditions) delivers a 25% increase in mean monthly flows. The other extreme, that of a 20% decrease and the same warming (defined as the 'dry' conditions) creates a 28% decrease in flows. Figure 2 shows the variation of mean monthly river flow with changes in temperature and precipitation. The contours show combinations of temperature and precipitation and the resulting change in flow.

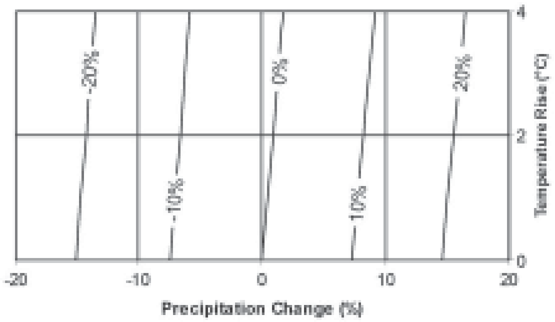

Figure 2. Percentage change in river flows with uniform changes in precipitation and temperature

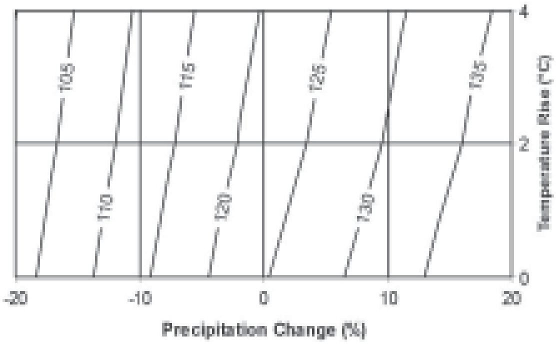

Figure 3. Mean monthly production (MWh) with uniform changes in precipitation and temperature

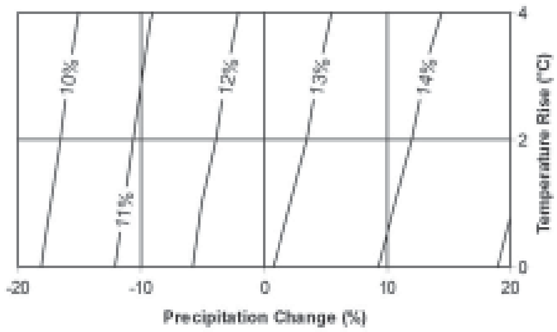

Figure 4. IRR (%) with uniform changes in precipitation and temperature

The changes in river flows impact on production and, as Figure 3 indicates, production rises with precipitation. While the proportionate changes are smaller in magnitude than the changes in river flows, they are still significant: under dry conditions production falls by almost 20% while under wet conditions rises by over 9%. The smaller changes seen with increases in rainfall are due to the fact that proportionately greater durations are spent with the turbine operating at maximum capacity.

Revenue follows a similar pattern to production. However, with the relatively high capital costs, the Internal Rateof Return (IRR) is very sensitive to changes in precipitation, particularly reductions, as the tighter packed contours in the left hand side of Figure 4 indicate. Again for illustration, dry and wet conditions result in IRR changes of –29% and 13%, respectively.

The key benefit of this approach is that it enables the identification of the project's critical climate variables, i.e. the combination of values of precipitation and temperature that result in the project becoming marginal in terms of its economic viability. Clearly, this is dependent on investor preferences and their minimum return requirements: the lower the minimum expected return the greater the margin of safety. As an example, this is assumed to be 10% with the critical climate values being those that deliver this IRR; the 10% contour line in Figure 4 shows such values. By inspection it is apparent that as temperatures rise, the tolerable decrease in precipitation is educed: with no temperature rise the scheme can tolerate around an 18% reduction in rainfall but with 4°C rise the margin is reduced to just over 15%.

CLIMATE MODEL SCENARIOS

One of the key projections from climate models is that there will be significant seasonal differences in warming and precipitation changes. The uniform changes used earlier do not take these subtleties into account. For the UK there appears to be a general trend towards wetter winters and drier summers (UKCIP, 2002), exacerbating current seasonal differences. To illustrate these effects, projections from the UK's Hadley Centre Regional Model have been used. Although driven by a larger-scale model, the Regional model operates on a 50 km grid, providing a far higher resolution representation of current and future climates than the global climate models. Figures 5 and 6 show the annual, winter and summer changes in temperature and precipitation, respectively, expected by the 2020s assuming a scenario of continuing high levels of carbon emissions Within some of the diagrams there are portions of land that are coloured white within which the expected changes fall within the natural variability of the climate. All other shades indicate changes that are outside these limits and represent statistically significant changes in behaviour.

Figure 5. Annual and seasonal temperature change in the UK by 2020, adapted from UKCIP (2002)

Figure 6. Annual and seasonal precipitation change in the UK by 2020, adapted from UKCIP (2002)

In Figure 5 it can be seen that for the majority of the UK and Ireland – including the area surrounding our case study – the annual warming is between 0.5 to 1°C. For the very south of England and the Continent the warming is half a degree higher still. In winter the warming is less pronounced but in the summer it is clear that a far larger part of the country will experience higher temperatures, albeit that the case study is fractionally too far to the north tofall into this zone.

Figure 6 shows that on an annual basis, there are decreases in precipitation of up to 10% over a significant fraction of the UK, particularly in the south and east. For much of the rest, there will be changes although these are not expected to be outside the range of the natural climate. The difference between winter and summer changes is remarkable. Winter rainfall is expected to increase by 10-15% for most of the UK (apart from western Scotland), with slightly larger increases in some parts of eastern Scotland. Summer will see a drying trend, with all but the west and north of Scotland seeing reductions in rainfall of between 10 and 20% and most of the remainder experiencing about half the level of change. In each of the projections the case study area is shown to experience significant seasonal and annual changes in precipitation.

Hydro schemes built towards the 2010 and particular the 2020 targets will increasingly experience a climate closer to that of 2020 than the climate experienced over the later decades of the 20th century. Economically, the major issue is whether the scheme has repaid its debts. Plant built in the 1990s will likely have repaid its loans and so the risks of reduction in income through changes in climate will have a less significant effect. However, those commissioned towards 2010 and after would likely still be servicing debt.

Ideally, the way to assess future changes would be to take the time series output of many climate models and form a decision tree on the basis of the projected financial indicators. In this relatively simple example, the aim is to illustrate the effect of non-uniform changes in precipitation and temperature, rather than provide an exhaustive analysis. We can get a feel for the impact the changes projected for 2020 would have by re-running the spreadsheet model using the historic climate data and perturbing it using the forecast changes.

Table 2 shows the projected precipitation and temperature changes for the area in the vicinity of Ormiston Mill. The seasonal differences are clear and these have an effect on seasonal flow. While annual changes are relatively small, there is a clear increase in winter flows and an even greater decrease in summer flows. In production terms, the turbine capacity limit means that virtually no additional power is produced during the winter relative to current conditions. However, the significant drops in summer flows mean that the scheme is idle for more of the season and consequently production drops by over a fifth. Fortunately, the larger potential in winter means that annual production is impacted to a lesser degree although the drop is still appreciable. Financially, the impact of these conditions would be modest, reducing IRR by around 0.8 percentage points, well within the margin of safety.

Table 2. Projected changes in climate and implied changes in river flow and production

Projected change	Annual	Winter	Summer
Temperature	+0.84°C	+0.57°C	+0.98°C
Precipitation	–1.84%	+4.84%	–9.45%
Monthly river flows	–1.73%	+4.51%	–13.74%
Mean production	–4.86%	+0.02%	–21.27%

A rapid comparison with the earlier results from applying uniform changes in climate (Table 1) suggests that the earlier results underestimate the potential change. The annual changes in precipitation and temperature imply that production and IRR would decrease by about half that projected by the climate model scenario. This reinforces the idea that it is preferable to use climate scenario data where available.

ADAPTATION

The issue of adapting to climate change is a common theme across many vulnerable sectors. In the context of minihydro, what scope exists for adapting schemes to potentially altered river flow regimes by altering a project at the design stage or by retrofit at a later date? Adaptation at a river basin scale has been examined to some extent in Reibsame et al. (1995) which dealt with the management of climate impacts in the Zambezi. At the plant level, Weyman and Bruneau (1991) found that the least cost optimal design of a large hydro scheme in Quebec, Canada altered with climate change, as changes in river flows increased the marginal costs of the scheme and reduced the firm energy production. Various technical means have been suggested for reducing the impact of changes in flows on water supply and hydro production. These include increasing reservoir storage (Cole et al., 1991) which implies raising dam height, increasing turbine efficiencies and lowering intakes to increase active storage (Reibsame et al., 1995). There are, however, fewer options available for smaller, particularly low head, run-of-river schemes as:

- there is no storage to speak of,
- the low head limits the possibility of using alternative turbine types,
- future efficiency gains on crossflow turbines may be difficult, and
- increasing the weir height to raise the head would be costly and potentially environmentally unacceptable.

As such, the only real option is to vary the turbine capacity.

In this case and given that this climate model forecasts increased and more variable flows, an increase in the turbine capacity would enhance capture of the winter flows, albeit at the expense of raising the minimum flow requirements and reducing summer capture further. The selection of optimal turbine size is a standard component of small hydro planning and therefore consideration of this in the context of climate change is fairly similar. In this case, an additional incentive may be that winter-time production is more valuable. Hence, the ability to capture greater volumes of winter flows could be relatively beneficial although the cost implications of a larger turbine and potentially larger penstock would need to be considered. The question remains however, should a developer make decisions on the basis of a ‘potential’ change? Unfortunately, the framework for answering this question is rather complex and a demonstration of it is beyond the scope of this paper.

CONCLUSION

While the literature contains

examples of climate impacts on the production and economics of larger schemes, little or no consideration has been given to the impact on smaller hydro, despite the fact that the lack of storage makes smaller hydro potentially more vulnerable to changes in river flows. Two example analyses have been applied to a potential mini-hydro scheme in the Scottish Borders; one a simple sensitivity study is useful for preliminary studies and identifying the tolerable change. Its failure to represent seasonal changes in climate means it may understate the potential changes although the application of change scenarios based on the output of global and preferably regional climate models goes some way to alleviating these difficulties. The need to consider multiple scenarios to cover the uncertainty inherent in climate impact assessments makes analysis and consideration of adaptation measures rather complex.

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*(**Source:** Proceedings of Hydropower '05,Stavanger, Norway 23-25 May 2005)* ■

Vietnam continues mini hydro drive

Song Lam Construction and Investment, a privately owned Vietnamese company, is planning to develop two hydro plants with the combined capacity of 16.4MW in the northwestern province of Son La, state media reports.

The developments, at a cost of US$20M, are the 7.5MW Nam Chim 2 plant and the 8.9MW Nam Chim 3. A schedule has not been disclosed.

In addition, Hoa Long Company, another privately-owned enterprise, is set to develop the 1. 9MW Doal 3 hydro plant in the central highlands provinces of M,Drak district.

In related news, Petrovietnam Finance Company has signed a US$25M finance agreement with the Song Da Corporation for the development of the Nam Chien hydro station, also in Son La province.

*(**Source:** 26 May 2006 IWP&DC)*

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Land Use Pattern for Piluwkhola Small Hydropower Project

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Abstract

Piluwkhola Small Hydropower Project (3000 kW), developed by private entrepreneurs, is located in the Eastern part of Nepal and lies in a tropical region between latitude 27^{0}15'53" and 27^{0}17'8"N, and longitude 87^{0}19'29" and 87^{0}20'51"E. The project was built within a period of 30 months. Nepali experts built the civil and metal works of the project; the electro mechanical machinery was imported from Germany. The unique features of the project are its 3487 m long steel penstock pipe from the forebay to the powerhouse and the fact that all hardrock was chiseled by hand. No blasting was used for the total alignment of 3.5 km.

Initially, a total of 4.99 ha land was estimated to be used for the project whereas 5.92 ha land was used finally. Of the total land used 2.63 ha (44.4%) is government land and 3.29 ha (55.6%) is private cultivated land. Private land was obtained by mutual agreement with the landowners. The land was categorised under different forms of payment. The government land was obtained on a lease for 40 years from the government at a payment of royalty with increased at the rate 10% each year for the lease period. Of the total land used, 23% was occupied by the permanent structures while the rest is used for access road, greenery, etc. The access road, also a vital link road to the villagers, passes along the penstock alignment as well as above it.

Of the total land excavated, 65% is soft soil and the remaining 35% is hard rock. Soft soil was excavated manually and with an excavator, while all hard rock was excavated manually using "ghan" and "chino", a primitive technology. Excavated soil was dumped along the alignment and reused for backfilling and access road embankments. Slopes above and below the alignment are protected by providing gabion wall and stone masonry walls as well as by bioengineering practices. The project tried its best to minimize the use of land, which is one of the indicators to make the project environmental friendly.

BACKGROUND

The Piluwakhola Small Hydropower Project, located in the eastern part of Nepal, has an installed capacity of 3 MW, and was planned and developed by local private entrepreneur of Nepal. The project is an important outcome of the liberal policy of the government of Nepal. His Majesty's Government of Nepal adopted the liberal policy in 1992, encouraging the private investors for the development of hydropower schemes. Before, the government body, Nepal Electricity Authority was the only authorized organization to develop, transmit and distribute the electricity for projects greater than 100 kW.

The construction of Piluwakhola Project is a successful story of a hydropower project by a private entrepreneur in the history of Nepal. It is also the cheapest project in Nepal. Initiation of the project was started on May, 1998 whereas it came into real construction on April, 2001. The construction work of the project was completed in 30 months. Local finance and human resources were used to implement this project. It came into commercial operation on 18 September, 2003.

PROJECT LOCATION

The project is located in the mid hills of Sankhuwasabha district of Nepal that lies in the tropical region. The district is the richest place for natural beauty and resources. Mount Makalu (8463 m), Makalu Barun Conservation Area, Rhododendron Conservation Area, Arun River Valley and the World's deepest Arun Valley are located in this district.

The project lies between 27^{0}15'53" E to 27^{0}17' 8" E, and 87^{0}19'29" N to 87^{0}20'51"N. This is a 7 hours walk from the STOL airport Tumlingtar in the same district. A dry season road passes through the powerhouse site of the project. The powerhouse of the project is 140 km away from the East-West Highway. Of the total approach road length, 80 km road is blacktopped, 24 km is graveled road and 36 km is an earthen seasonal road that opens only for six months, while during the rest of the year, the road will have big pits and some parts of the road will have washed away.

PROJECT FEATURES

It is a run-of-river type project. A 16 m long diversion weir across the river was built to divert water into the intake. Intake and flushing gates were constructed for regulating the flow of water. A double Dufour chambered type desilting basins with dimensions 47.5 m x 5.6 m x 6 m each is used for settling sand and suspended particles. A small forebay pond is constructed just behind the desilting basin. From the forebay, a 3487 m long headrace penstock pipe with a diameter ranging from 1620 mm to 1320 mm brings the water to the powerhouse. The penstock pipe was welded and supported by saddle supports and anchor blocks at every bend. The penstock pipe lies above ground as well as under ground. The mild steel penstock pipe is painted at inner and outer surface. It ends at the butterfly valve of the powerhouse. Two sets of generators and turbines, with all accessories are installed in the powerhouse. The electricity generated from the powerhouse is transmitted through a 33 kV transmission line and is synchronized into the national grid at the substation located 540 m away from the powerhouse.

CONSTRUCTION WORK

Most of the construction work was fulfilled by manual process and took 30 months to complete. Eight hundred people worked during the peak construction period. Two excavators were mobilized for excavation and site clearance. Two tractors were used for transportation of penstock pipe. A temporary workshop was built at the project site for the metal works. Steel plates rolling, welding, and constructing of 3 m long units of penstock pipe was done here. The rust of the penstock pipes was removed by acid bath. Electricity was available throughout the alignment for welding, and a 250kVA diesel generator was installed for backup power.

LAND CLASSIFICATION

On the basis of ownership, the land of the project area was of two types: private and government land. The private land has four categories – *abbal, doyam, sim* and *char* on the basis of productivity of crops. This is a traditional governmental land classification. The land having the highest productivity and irrigation facility is referred as *abbal* and the land having the least productivity is referred as *char*.Similarly, land with intermediate productivity is referred as *doyam* and *sim*. The government land used by the project was ditches, bushy land and forestland. The forestland is covered by tropical and subtropical flora and is managed by community forest user groups.

LAND OBTAINING PROCESS

The government land covered by forest was obtained from the Department of Forest on lease agreement for forty years. There is a fixed rate of lease for the first year and a 10% annual increment on the first year's rate throughout the lease period. The project paid for the loss of trees to the community forest user groups. Private land required for the Project was acquired from the local community by registration pass. The rate of private land was fixed through the discussion with the landowner and the local community on the basis of land type - *abbal*, *doyam*, *sim* and *char*. A mutual understanding was made between the community and the project. Lands for temporary uses were obtained by the mutual agreement with the individual landowners.

LAND USED BY THE PROJECT

The developer obtained terrain land in the project area for permanent as well as temporary uses. The land for the construction of labour camp houses, sheds and construction materials preparation was for temporary use and it was obtained on lease basically during the construction period. The land that has been used for the construction of permanent project structures, access roads, and office cum staff quarters was of permanent use.

Initially, a total of 4.99 ha land was estimated for the scheme whereas 5.92 ha land was used finally. Of the total land used 2.63 ha is government land and 3.29 ha is private land. The private land comprises irrigated land, upland with no irrigation

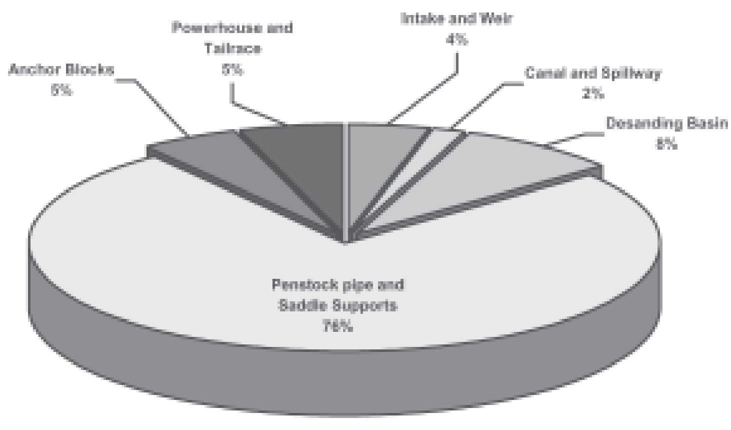

Fig. 1 Permanently Land Used by the Project Structures (%)

facility and forestland. A 10 m wide landstrip was obtained for the construction of the penstock alignment and access road throughout the project length. Of the total land obtained by the project, only 1.25 ha (21.04%) land has been permanently occupied by structures. Of the remaining land the major part of land has been occupied by the access road through out the alignment and a remaining small portion of land is used for vegetable farming, plantation and construction materials collections. Permanent land occupied by the different project structures is shown in Figure 1.

LAND EXCAVATION AND PROTECTION

Excavation was needed by the project for the clearance of the penstock alignment, construction of access roads, saddle supports, anchor blocks, desilting basin, the powerhouse and for collection of construction materials. In a 3.5 km stretch of alignment, 65,290 m^3 land has been excavated. Of the total land excavated 65% is soft soil and 35% is hard rock. The quantity of excavation at different places is shown in Figure 2. The soft soil was excavated manually and by excavator while hard rock was excavated by chiseling. The soil excavated at the penstock alignment was reused for back filling into the alignment, for the embankments of access roads while the soil excavated at the headwork and powerhouse was used for river protection. The unstable sections of the alignment are protected by the gabion and stone masonry walls above and below the alignment. Also, shrubby type local vegetation that help to anchor the soil were planted at unstable area. Of the total penstock alignment 34.7% is buried and the remaining 65.3% lies above ground.

Fig. 3: Chiseling of Hard rock at Piluwakhola Project

CHISELING

An amazing feature of the project is the breaking of hard rocks throughout the alignment, accomplished by Chiseling, a primitive technology. During Chiseling *ghan* (Hammer) and *chino* (Blade) were used. Of the total excavated soil, 35% of the hard rock was broken by hands. No explosives were used.

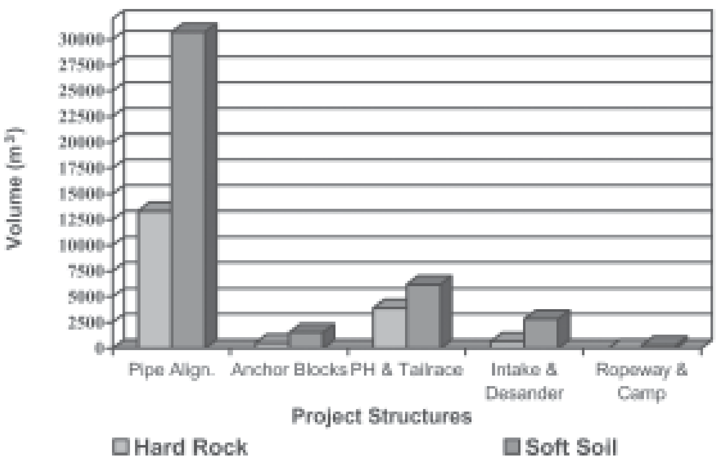

Fig. 2 : Land Excavated at Different Sites

CONCLUSION

The Piluwakhola Small Hydropower developer has acquired the cropland and forestland to build the project. The price of the land was agreed upon by mutual understanding between the two parties, which is one of the positive indicators of this endeavor. There was less excavation of land as compared to an open headrace canal for water conveyance system. Similarly, the width of the penstock alignment was taken so economically that there was less acquisition of valuable land. The excavation of hard rock by chiseling was a great achievement of the project. The above shows that this project was build with very little environmental damage.

REFERENCES

AVHDC (2001), Initial Environmental Examination (IEE) Report of Piluwakhola Small Hydropower Project and 33kV Transmission Line, Arun Valley Hydropower Development Company (P.) Ltd, Kathmandu, Nepal.

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HRC's expert attended project appraisal of " Management of Hydro Power Development 2005, Part II "in Vietnam

At the invitation of SwedPower International, Sweden, HRC's expert, Mr. Jianda Zhao attended the Part II of the Training Programme —"Management of Hydro Power Development 2005"- in Vietnam (from April 1 to 8). The mission was totally sponsored by SIDA.

24 participants from Asia, Middle East and Eastern Europe attended the programme. During the mission, the organizer arranged a series of international academic exchanges and visit to Ho Chi Minh and Hanoi. The participants also visited Hoa Binh hydropower station (the biggest one with total installed capacity of 1920MW at present in Vietnam) and Tri An hydropower station, with installed capacity 400MW. Swedish embassy in Vietnam hosted all international participants in the embassy.

According to requirement of the Seminar, a report submitted by Mr. Zhao was appraised by Swedish experts and other international participants. The report was highly affirmed and estimated by the organizer.

Using the opportunity of this international activities, HRC's expert briefed the achievements in China's hydropower development particularly the rural hydropower and electrification as well as HRC. Meanwhile, Mr. Zhao explored the hydropower cooperation with officials from Ministry of Energy of Albanian and reached an agreement of electric equipment supply for 4 hydropower sites by HRC. He brought back some related data of the 4 hydropower sites. The follow-up work will hopefully stimulate the economic cooperation.

Visited in Hoa Bin hydropower plant in Vietnam

Cover: Water intake of Tri An hydropower plant, Vietnam

The Tri An hydropower plant, with an installed capacity of 400MW and 1.7 Twh/year generation is located on the Dong Nai river at 65 km from Ho Chi Minh City,in the North-East direction.

This hydropower plant serves as a prime force in enhancing the socio-economic development of the Southern Vietnam. The main function of Tri An is energy production for the country. In addition, it also provides irrigation water to Dong Nai,Song Be provinces and Ho Chi Minh City and contributes in driving back seawater penetration.

The project was completed in 1991, after 7 years' construction with full support of the Government of Vietnam,effective cooperation of the USSR(former) and the meaningful contribution of the people in the Southern provinces and cities.

Machine hall

Visited in Tri An hydropower plant(The third to right: ***Mr.Le Quy Anh Tuan***, Operation Manager of the plant)

Tail water of the powerhouse

General view of powerhouse and 220kV switchyard(on the upstream side)