Small Hydropower Development in the Context of Climate Change

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ABSTRACT

This paper discusses issues confronting development of small hydro power (SHP) schemes in the context of climate change. Due to the nature of system as well as operational model SHP are vulnerable to climate change impacts. At the same time, increased global concern in reducing GHG emissions has created an extremely positive atmosphere for hydropower development. Many international incentives are available for the development of programs that can create a strong national foundation for long-term development and popularization of SHP development schemes. While the major attraction is the high level of reduction of GHG emissions compared to fossil fuel based power generation, especially in off grid development scenarios, SHP schemes can provide a strong basis for poverty reduction and development through community based SHP management. This can also be viewed as an adaptation strategy that can assist transforming farming sectors adversely affected by climate change conditions to industrial sector.

1 APPEAL OF SHP IN COMBATING CLIMATE CHANGE IMPACTS

1.1 Role of Small Hydro Power in the context of Climate Change

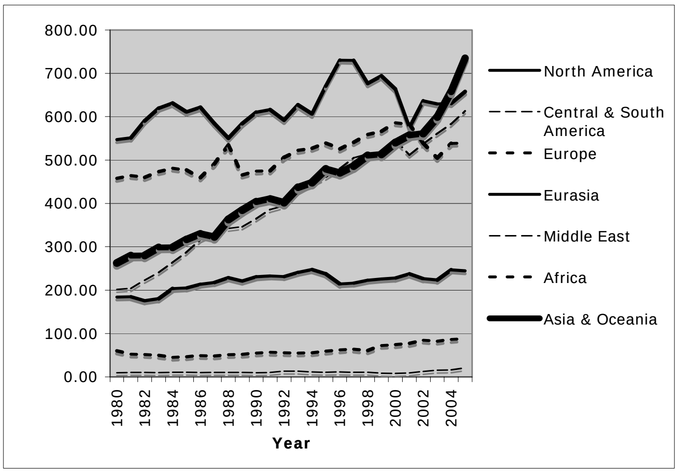

Fig. 1: Global hydroelectric net consumption (source: International energy annuals, 2005)

Renewable energy development has become a priority in the energy development agenda as governments around the world has recognized the need to substantially increase RE share in national power sector to meet the GHG emission reduction targets agreed under Kyoto Protocol. Hydropower, has the highest share globally in the RE sector as potentially available as well as currently utilized. According to International Energy Annuals 2005, by DOE, USA, hydropower development continue to grow in many parts of the world, while it is has a high growth rate in Asia and Ocenia region and Central and South American regions, which are poised to become world leaders in hydropower generation, as can be seen in Figure 1. This widespread use of hydropower globally and its rapid expansion in the fast developing Asian as well as Central and South American regions is conducive to the expansion of range of hydropower production means to include mini, micro and pico hydropower as supplementary facilities. Such Small Hydro Power (SHP) facilities have a unique status, not only in the context of energy development but also as a development opportunity that can incorporate poverty alleviation and community participation. Fig. 2 shows the share of Renewable Electric Power production globally at the end of year 2004 (source: Ren21, 2005). As can be seen in Fig. 2, next to large hydro, SHP has the second highest share at around 7% in RE

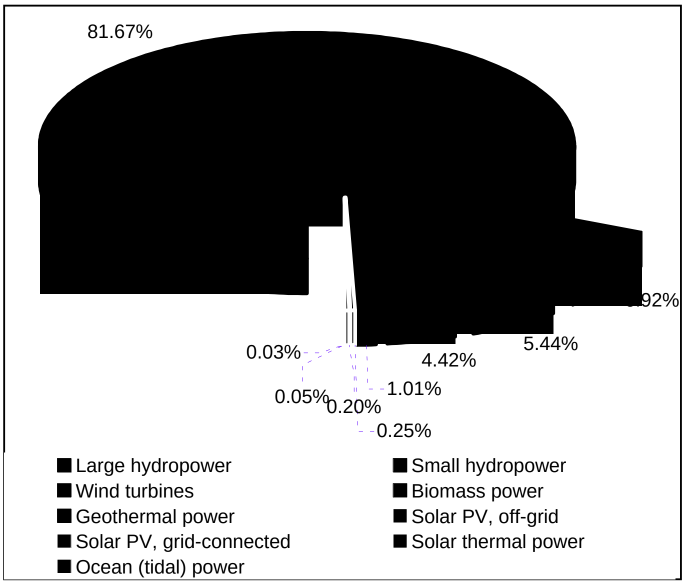

Fig. 2: Renewable Energy share at the end of 2004 (source, Ren21, 2005)

electric power production in the world. SHP's advantage in the low capital requirement is a major attraction to deploy them in rural areas that are not serviced by the grid. Emerging global commitments to combating adverse effects of climate change is providing additional mechanisms to expand the use and deployment of SHP. Such support stems from the recognition of direct global benefits associated with the GHG reduction compared to alternate forms energy production from a of fossil fuel based energy mix, as well as due to its promise of sustainability and poverty reduction potential. However, small scale and independent nature of SHP also makes them vulnerable to external threats. Especially, as they have little or no storage, power production may be affected by the changes to flow regime brought about by climate change impacts. Similarly, if the case of water resources reduction, it is possible that SHP may lose flows to competing water demands from existing users such as irrigation who may have long standing water rights compared to recent SHP schemes. While the exact impacts would depend on local characteristic such as landuse, catchment extent, slopes, ground water conditions and soil properties in addition to future local weather patterns under future climate scenarios, some general trends can be identified with known climate change characteristics.

1.2 SHP development environment

Unlike large scale Hydropower development, SHP development does not attract large agencies or corporations. Either small-scale companies or individuals mainly carry SHP development, and the success and the extent of SHP deployment may depend to a large extent on the supportive government policies and incentives. According to "Renewables Status Report" (ren21, 2006) US$ 38 billion has been invested in renewable energy in 2006 without counting large hydropower development. The technology share of this investment are 37% on wind power, 26% on solar PV, 11% on Solar Hot water, 11% on SHP, 7% on Bio mass followed by 7% on geothermal. This share reflects the current increased focus on wind power and solar PV, which have grown 24% and 55% respectively in 2005. While SHP in 2005 increased by 8%, its addition to global renewable energy supply had been 5GW that year and second only to wind power contribution. Furthermore, a comparison of typical production of RE power generation options shown in Table. 2 shows that SHP, together with Geothermal power production has the cheapest production costs after large hydro. In addition to high return on investment, serving rural off-grid communities can be a major driving force for SHP expansion. Examples abound on the successful deployment of SHP plants in rural communities in Pakistan, (Ex. Aga Khan Rural Support programme received the Asden Award for Sustainable Energy for installing over 180 micro-hydro power units) Indonesia (pilot programs with GTZ), India, Nepal, etc.

Table 1: Typical Energy Costs (Source: ren21, 2005)

Power Generation	Typical Energy Costs (cents/kWh)
Large hydro	3–4
Small hydro	4–7
On-shore wind	4–6
Off-shore wind	6–10
Biomass power	5–12
Geothermal power	4–7
Solar PV (module)	—
Rooftop solar PV	20–40
Solar thermal	12–18

2 CLIMATE CHANGE IMPACTS

2.1 Climate change mechanisms that can have an impact on SHP development

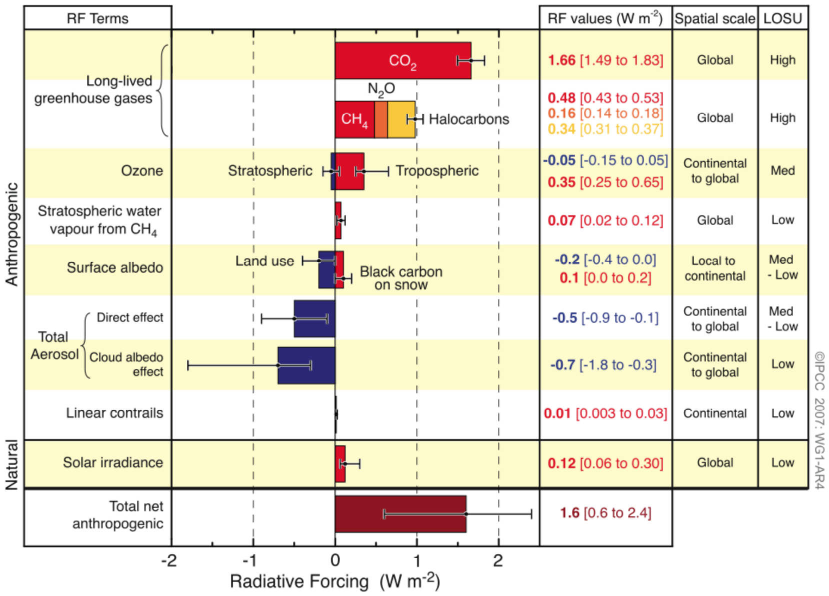

Fig. 3: Summary of Climate Change mechanisms (from IPCC AR4, WG1, SPM2)

The climate change radiative forcing as summarized by the working group 1 report 'Summary for policy makers' of Intergovernmental Panel on Climate Change (IPCC) in Assessment Report 4, is shown in Fig.3, which shows the two different types of radiative forcing, negative as well as positive, which leads to global dimming (cooling) and global warming respectively. As the positive radiative forcing is higher than the negative forcing, the net result is positive radiative forcing that produce a warming globe and associated consequences. Howerver, it is also important to note that a significant part of the world is also affected by negative radioactive forcing impacts during some parts of the year. While the positive radiative forcing results from GHG emissions, aerosol is mainly responsible for energy absorption and scattering that produce a cooler earth. Both of these mechanisms have significant impacts on local weather, hydrological processes and hence on the stream flow both in terms of magnitude and duration and as SHP are mainly designed without significant flow storage they are affected by variations of stream flow.

2.2 Global Warming Impacts

Global warming is basically expect to energize the global hydrological cycle, which would produce more intensive rain, high intensity-low duration spells, as well as more dry spells. Most of the climate change prediction models have converged in predicting temperature changes anticipated as a consequence of global warming, but the resulting rainfall change predictions, especially the extreme precipitation predictions are not consistent across models. In the forth assessment report (AR4) released in 2007, IPCC summarizes the consensus of global scientific community on the projected impacts of climate change. Within IPCC, the summaries of working group 1, which deals with physical science basis, and the working group 2 which focus on impacts, adaptation and vulnerability, are relevant in assessing the possible impacts on SHP. According to WG1 summary for policy makers report

- *Extratropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns, continuing the broad pattern of observed trends over the last half- century.*
- *Increases in the amount of precipitation are very likely in high latitudes, while decreases are likely in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100), continuing observed patterns in recent trends.*

WG2 summary for policy makers further identifies the threat of glacier melting as,

- *In Asia, glacier melt in the Himalayas is projected to increase flooding, and rock avalanches from destabilized slopes. Coastal areas, especially heavily populated mega-delta regions in South, East and Southeast Asia, will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from the rivers.*

From the above, it can be summarized that increased precipitation, thus increasing stream flow can be expected in high latitudes as well as streams fed by glaciers. In the other regions, the general trends of less rainy days, but characterized by high intensity rains, as well as prolonged dry spells, characterized by low flows can be expected. While the increasing precipitation could be attractive for SHP in the upper latitudes, SHP are more vulnerable to the changes of intensities as there is little or no storage capacities to absorb these fluctuations. The exact level of these changes, however, would depend on the characteristics of the catchment as well as the local precipitation patterns that could be significantly different from the regional average values. The appropriate way to understand these vulnerabilities is to use time series output from climate change prediction models and feed them to an appropriate hydrological model to derive the stream flows and then to compare the new flow duration curves with the historical curves. Unfortunately, most of the climate model outputs are too coarse in spatial domain compared to the small catchments that supply SHP plants, and hence downscaling, either through statistical methods or using local area numerical simulation models that produce high resolution rainfall values based on the global data outputs, is required.

At the same time it must be borne in mind that such changes have been observed in many parts of the world and that there could have been a gradual change in flow patterns. Thus a certain amount of self-adaptation might have occurred without realizing these changes, or a certain degradation of performance could have occurred. An analysis of rainfall trends in Sri Lanak (Herath and Ratnayake, 2004) based on observed rainfall has shown that rainfall intensity-duration curves could have changed during the two periods considered, 1964-1973 and 1984-1993 as shown in Fig. 4. As can be seen in the figure, the hourly rainfall intensities are higher for 5-year return period during the later decade, but they are similar at the 6-hour duration interval. However, the impact of this change on flow pattern may still be different in different catchments. Higher rainfall intensities produce more runoff, but this again depends on the soil conductivity as well as land cover and surface depressions. The effects could be quite visible in small catchments where time of concentration is less than 6 hours, but for large catchments, the effect could be smaller. At the same time, higher rain intensities would produce more direct runoff and less ground water recharge, thus reducing river low flows. Combined with expected long dry spells, this means a flow duration curve could change, with higher flows increasing and low flows reduced.

What kind of adaptation measures should be taken? In fact, there are not many options that can be easily adopted. It is unlikely that the storage of SHP is increased to accommodate stream fluctuations due to large costs and possible adverse environmental impacts. The likely solution may be to increase the capacity of the turbines to accommodate increased flow components. Generally the turbines are designed to optimize power production considering trade off between using high flows to maximize production and the ability to operate during low flows, based on flow duration curves. Thus it is important to investigate the impacts of climate change on flow regimes and consequently on the flow duration curves of streams harnessed by SHPs. However, localized studies would be required to assess feasible ranges and individual operators may not take up the task of carrying out such studies on future expected climate change impacts. Thus it would be appropriate to prepare vulnerability maps at national level that describe the changes expected in flow duration curves due to climate change, supported by the government, as basic information related to climate change to develop strategies to accommodate future risks due to global warming.

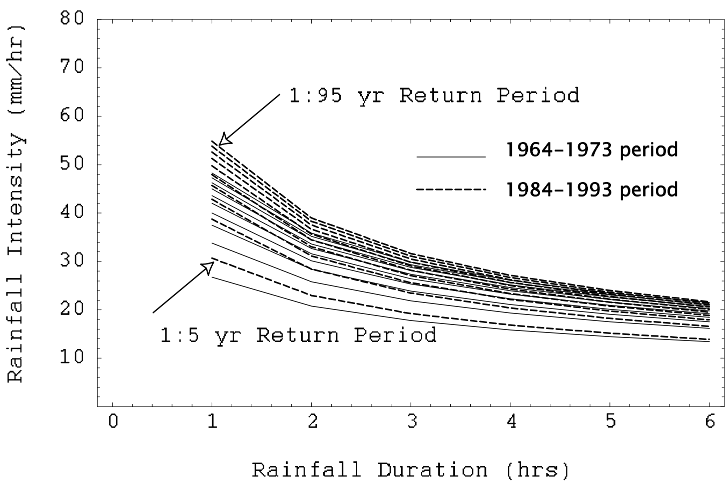

Fig. 4: Rainfall intensity-duration curve changes in Sri Lanka (source: Herath and Ratnayake, 2004)

2.2.1 Global Dimming Impacts

The second form of climate change, global dimming, due to negative radiative forcing indicated in Fig. 3 is caused by the presence of aerosols in the atmosphere. The phenomenon has been first verified by an international study, the Indian Ocean Experiment, or INDOEX, that there is a thick layer of haze hovering over the Asian region, prevalent in the dry season from December to April. Named as the Atmospheric Brown Cloud, it covers most of the tropical Indian Ocean bounded approximately between the latitudes 25°N and 5°S, and spreads over an area far beyond the sources of pollution. Recent observations have shown this phenomenon to exist in many other parts of the world too, notably over South America, South East Asia as well as parts of Europe. The major impact of global dimming is the reduction of photosynthesis as a result of decreased solar radiation reaching the surface leading to reduction in agricultural productivity. In addition, the energy absorption by the atmosphere can have a direct impact on the cloud formation and hence on the rainfall. The reduced temperature at the ground surface may affect the evapotranspiration that would adversely affect the long-term rainfall trends. To clarify these issues a numerical modeling study has been carried out for central Srl Lanka. The global weather model outputs have been used in a local area model (DRF) in which the radiation scheme has been changed to accommodate the aerosol impacts. A three step nesting numerical simulation process was carried out to obtain 4 km spatial rainfall and temperature time series data for 6 months at 10 min resolution with and without ABC conditions (see Pathirana et. al, 2006 for details). The comparison summarized in Fig. 5 shows that while the small rainfall amounts are drastically reduced, more than 30% in the range of rainfall values less than 5 mm/day, the effects on high rainfall, especially those above 40 mm/day are negligible. Therefore we may conclude that there is no significant impact by

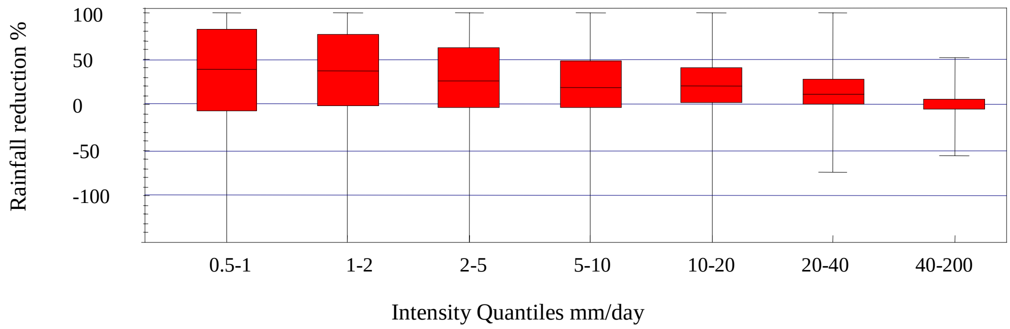

Fig. 5: Reduction of rainfall due to ABC impacts

global dimming on hydro power production, except for possible low flow reduction.

2.3 SHP impacts on mitigation and adaptation to climate change

While climate change has an impact on SHP, SHP also plays a very important role in combating global warming. For off grid situations, SHP will replace power production from diesel fuel oil and will have a CO2 emission factor of 0.975 ton CO2/MWh. For the on-grid case the factor will depend on the energy mix of the country and may range from 0.5 – 0.8 ton CO2/MWh (for Japan it is about 0.5 while for Indonesia it is about 0.74). SHP development therefore is a very attractive energy alternate in GHG emission reduction and can be considered as an important mitigation mechanism.

SHP can also play an important role in supporting adaptation to climate change. In the section 2.2.1 it was noted that high intensity rainfall will not reduce substantially due to global dimming, thus having a small impact on hydropower production. However, global dimming affects agriculture production very significantly. In a follow up to the above study it was found that the 2nd season rice yields in Sri Lanka could be reduced by about 15% due to global dimming (Herath et. al, 2006). Similar studies carried out in India points to about 10-20% reduction of rice yield due to global dimming. Alternate livelihood provision is one of the options in rural areas to counter these adverse impacts on agriculture. Rural electrification through SHP can be designed as a national development policy where rural communities can own and operate SHP, and further utilize surplus energy to develop new small industries. Such planning addresses both mitigation and adaptation needs brought about by climate change.

3 POLICIES FOR SHP PROMOTION

The resources and mechanisms available under climate change activities are specially suited for SHP development. Under Clean Development Mechanism, which provides opportunities for developed nations to meet their emissions targets by implementing projects that certify emission reductions in the developing nations, more than half of the registered activities are energy production related and energy industries has the highest number of approved methodologies. Recently established adaptation fund under UNFCC is replenished in part by the CDM activities and is available to carry out adaptation projects in countries affected adversely by climate change impacts. The Global Environment Facility (GEF), manages the financial mechanisms of UNFCC and disburses about US$250 million annually on mitigation and adaptation activities related to climate change.

In the developing countries above mentioned financial incentives can be used by the governments to develop long-term SHP expansion programs. Community based SHP development where the plants are owned and operated by rural communities can be especially attractive in this context as they can be utilized to reduce poverty could provide strong foundation for sustainable development. Some pilot projects in this direction have already been carried out sucessfully in a number of countries, such as Pakistan and Indonesia. In a typical case a management committee will be established by the community responsible for operation and management of the hydropower facility. The community can decide the tariff for household connections and rural industries according to the local economic conditions and community needs. While most of the installation cost may be recovered from such income, additional funds for setting up a framework, capacity development and long term education of the population on SHP can be done by the governments based utilizing global support funds.

For the developed countries too, SHP offer distinct advantages in efforts to meet emission targets. In fact after China, USA and Japan are the leaders in the deployment of SHP. Recently, in Japan there has been a rapid expansion of pico hydro, mostly by individuals to meet their local demand. Many citizens get involved in such deployment as their personal contribution to reduce global GHG emissions. Pico hydro is also well established in some developing countries such as Viet Nam and China. Further support to this industry including research efforts to utilize still under developed flow regime of very low head (under 1m) can lead to new uses in areas such as irrigation, drainage as well as head differences in urban water supply-drainage systems.

4 CONCLUDING REMARKS

Mitigation and adaptation needs of climate change are providing an unprecedented favorable environment for the wider use of small hydropower development schemes. Governments of developing countries as well as development agencies should take advantage of these incentives as well as public and private support for renewable energy development to incorporate SHP in long term development plans, especially as a means to raise the living standards of rural communities. At the same time new research and development efforts can lead to much widespread use of SHP especially pico hydro level by various segments of society as a societal contribution towards GHG emission reduction.

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