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Sharing knowledge, experiences, and innovations in public-private partnerships in infrastructure

Taking a holistic approach to planning and developing hydropower

Lessons from two river basin case studies in India

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Planning for hydropower development needs to evolve from a project-based engineering approach to a more holistic one—an approach incorporating river basin planning and integrating potential social and environmental issues across multiple projects and the entire river basin. Such a framework would help to optimize the benefits and minimize the costs. It would also bring stakeholders together to weigh opportunities and risks and form a consensus for sustainable and equitable development. A PPIAF-funded study on two river basins in India's Himalayan region outlines steps for moving toward such a holistic framework.

The chronic shortage of electricity supply in India impedes economic development and poverty reduction. More than 40 percent of households, most of them in rural areas, lack access to electricity. With the aim of extending access to electricity to all households by 2012, the government has launched a program to add 100,000 megawatts of generating capacity. Recognizing that meeting much of this need with hydropower, a renewable energy resource, offers many advantages, the government calls for its expansion from 24 percent of the country's generation capacity today to almost 40 percent by 2012.

With this national development objective in mind, Himachal Pradesh and Uttarakhand, two states in northern India, have launched ambitious programs to harness their substantial hydropower potential. Himachal Pradesh has identified more than 20,000 megawatts of hydropower potential, with less than 7,000 megawatts developed. Uttarakhand has nearly 15,000 megawatts of hydropower potential, with less than 3,000 megawatts developed.

Both states are pursuing an untried and thus somewhat risky strategy of attracting public and private developers to build and operate hydropower projects. A few projects are operating today—five on the Satluj River, in Himachal Pradesh, and one on the Alaknanda River, in Uttarakhand (table 1). The hydropower development plans for the two rivers call for a total of 50 projects, adding about 15,000 megawatts of capacity. Slightly less than half the projects have been allocated to the private sector; the rest have been distributed among state and central government hydropower companies.

These are significant development programs that face considerable challenges in ensuring effective coordination and efficient development and operation. Many of the private developers are new to the sector, and their ability to manage the hydrological, geological, construction, and commercial risks of the sector is still untested.

How the project approach falls short

Planning for hydropower development has traditionally been oriented toward individual projects. There are compelling reasons for a project-based approach. But this approach has several

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TABLE 1

Satluj and Alaknanda River projects by development stage and type of developer

Development stage	State government	Central government and central-state joint ventures	Private developers	Total projects
Satluj River projects				
Operating	1	3	1	5
Under construction	2	2	1	5
Under development	2	2	5	9
To be allocated	0	0	9	9
All planned projects	5	7	16	28
Planned capacity (megawatts)	780	6,387	3,555	10,722
Alaknanda River projects				
Operating	0	0	1	1
Under construction	0	1	1	2
Under development	6	7	4	17
To be allocated	0	0	2	2
All planned projects	6	8	8	22
Planned capacity (megawatts)	853	1,771	1,367	3,991

Source: Hydro Tasmania Consulting. 2007. "River Basin Development Optimization Study." Report prepared with support from PPIAF for the World Bank, South Asia Energy Team, Washington, DC.

limitations for sustainable development of an entire river basin.

An important one is its failure to take account of the power-system-wide implications of developing multiple generation projects on the same river. The capacity of a project to meet peak demand could potentially be compromised by other peak-load projects subsequently developed on the same river. And the development of a new project could create unexpected costs or, conversely, unexpected benefits for existing projects, such as by increasing or reducing the level of silt in the water.

Another limitation relates to assessing impacts. While the project-based approach entails an assessment of environmental and social impacts stemming directly from the individual project, other impacts may emerge—or may emerge in a more severe form—only when the entire river basin is taken as the unit of analysis. One example is the cumulative impact of multiple projects on soil erosion.

In addition, there are long-term planning concerns that typically fall outside the scope of an individual project. An example is the vulnerability of the river basin and related ecosystems to climate change, which could adversely affect a river's hydrological patterns and volume of water flows, the length and intensity of the monsoon season, or the frequency and severity of floods.

Basinwide planning can lead to more equitably shared benefits

Steps toward a basinwide approach

The system governing hydropower development in India today does not capture all the potential costs and benefits of developing multiple projects in a single river basin. Using the Satluj and Alaknanda Rivers as case studies, a PPIAF-funded study develops recommendations for moving toward a holistic, river-basin-wide approach to hydropower planning, design, and operation (Hydro Tasmania Consulting 2007). The recommendations are based on analysis of project documents, planning procedures, technical norms, hydrological modeling, and consultations with stakeholders. The guiding principle is to support improvement in existing practices rather than introduce entirely new systems and approaches, which may have time and cost implications. The following sections outline some of the recommendations.

Enhance coordination and data sharing

Successful implementation of the river basin approach will require close coordination among all stakeholders—from the project planning stage to the evacuation of power. In addition, efficiency and long-term sustainability in the development of the rivers for hydropower generation will require easy, uniform access to data on meteorology, hydrology, topography, ecology, and sedimentation. Such coordination and data enhancement could be achieved by:

- Pursuing cooperative development of tools and databases to bring basinwide considerations into project planning, design, and implementation. This process could be formalized through a central agency or independent body for maintaining data integrity.

- Establishing a developers' forum with strong participatory requirements and supporting mechanisms for data sharing and joint decision making.

- Assigning program responsibility and funding to a lead agency to facilitate river basin planning and development.

- In the long term, setting up an institution empowered to establish representative membership and assume responsibility for river basin planning.

Optimize production basin wide

Electricity generation is generally optimized on the basis of individual projects, without taking into account other projects in the cascade. This can lead to substantially lower energy output and project revenues than would have been achieved with basin optimization. With a cascade of generators, the total energy output can be increased by optimizing the scheduling of successive generators as the peak river flows progress downstream. Using mathematical modeling, the case study shows that optimizing the operation of two adjacent projects on the Alaknanda as a cascade (rather than the planned individual operation) would be likely to increase annual energy output by 230 gigawatt-hours, currently valued at some $14.5 million.

Moreover, developing a basinwide hydrological simulation model would help in understanding the effects of one project in a cascade on another. That would reduce project risks, encourage planning and operation on a broader scale, and allow planners and developers to understand how changes to one project might affect others in the system.

Improve yield estimation

The data collection methods now being used to determine hydropower output in project design are inadequate. First, only local, on-site data are considered in deriving water yields. Even though a significant part of both basins is covered by snow and glaciers, yield estimates from these areas are rarely given close consideration. But because the runoff from these areas is highly seasonal, including better estimates of these flows is critical, especially for the run-of-river schemes.

Second, yield calculations do not consider either upstream or downstream effects of water storage or operating rules. And third, yield calculations tend to use data from just one year (a 90 percent dependable year). But the data from a single year could be highly skewed, depending on the size of flows in the snow melt and monsoon seasons, leading to unreliable estimates of the water yield and thus energy output.

Estimates of the energy output of a run-of-river project should, at a minimum, consider power projects immediately upstream, since the timing of water flows from these upstream sites may dictate the timing of energy output at the downstream site. At the basinwide level it is important to consider the firming of seasonal river flows by optimized release from major upstream storage facilities, which can increase the output from individual power projects as well as the basin as a whole.

Hydrological yield estimation can be vastly improved through coordinated collection of hydrological and meteorological data and dissemination of those data to developers. Similarly, central studies could estimate the effects of climate change, an important aspect that individual developers are likely to ignore.

Develop shared infrastructure

Greater coordination in developing infrastructure such as access roads, power for construction, and transmission lines for power evacuation could help developers discover potential synergies. This would lower overall costs by reducing duplication between projects and allowing developers to pool costs. It would also reduce environmental impacts. An appropriate forum could bring the developers together to discuss infrastructure needs and reach a consensus on how to proceed.

Address sedimentation and water quality

Like all Himalayan rivers, the Satluj and Alaknanda carry very high sedimentation loads. These create severe operating and environmental problems, including erosion of turbine runners, adverse effects on water quality, and loss of storage area due to siltation. As the number of projects grows, sedimentation is likely to increase as a result of construction spoils and soil erosion. An upstream storage facility in each river basin could, by regulating overall flow, reduce silt loads downstream

Involving local representatives in early planning can build trust

as well as lead to greater energy output. In addition, a holistic, basinwide approach would provide opportunities for developing catchment protection measures such as revegetation and land stabilization—thus improving the overall water quality.

Strengthen flood risk assessment

Prescribed methods for estimating extreme floods in the basins (for the purposes of project planning and design) are not always consistently adapted and applied. The guidelines do not necessarily account for circumstances specific to the area, such as the flood runoff caused by extreme monsoon rains falling on snow-covered areas. Nor does it appear that any of the project developers have considered the combined probability of reservoir failure in a cascade of dams within a river basin. Thus both the methods of assessing the level and risk of floods and the application of these methods need improvement.

A basinwide flood forecasting and warning system would be useful to ensure that all downstream power projects and local towns and villages receive adequate warning in the event of a flood or upstream dam break. Developing such a system is beyond the capacity of any individual developer and should be coordinated by state and central agencies. This effort would require upgrading remote data-gathering sites, strengthening telemetry communications, and developing a central database and data processing capacity.

Assess cumulative impacts

A basinwide approach to assessing environmental and social impacts at the planning stage would help identify opportunities for maximizing benefits and mitigating or compensating for risks, leading to better outcomes for all those involved. The overall impact of developing multiple projects can be assessed through a process of cumulative impact assessment. Such a process would include analyzing current data, determining potential impacts and benefits, considering alternatives and cumulative effects, and developing avoidance, mitigation, or compensatory activities to minimize the overall impact.

This process helps in selecting the optimum combination of projects and sites—the combination resulting in the greatest benefit for the least impact. It also helps identify the best combination of a range of benefits through multipurpose projects. And it helps achieve greater certainty in defining project requirements as well as greater acceptance of those requirements by all stakeholders.

Involving local representatives in early basinwide planning, and ensuring good communication about the planning process, can build trust and understanding among all those involved. Moreover, local representatives can be involved in ways that go beyond participation in planning. For example, they could participate in monitoring the implementation of environmental management plans, catchment area treatment plans, and other plans to mitigate the social and environmental impacts of development.

Conclusion

Comprehensive river basin planning is a major undertaking. Establishing a baseline and developing the necessary skills, tools, guidelines, and operating framework could take several years, but this work could be completed in phases. Undertaking basinwide economic, social, and environmental assessments as well as basinwide yield estimations would be important initial steps.

There have been some positive recent developments for the move toward river basin planning. Stakeholders have shown strong support for coordinated data collection and analysis and are actively considering the role of an independent river basin development authority. In addition, developers and state governments have undertaken recent efforts to optimize hydropower projects along limited stretches of the Satluj and Alaknanda Rivers. But while encouraging, these efforts underscore the need for a more systematic approach to basinwide optimization, to ensure benefits for all developers, communities, and governments involved.

Reference

Hydro Tasmania Consulting. 2007. "River Basin Development Optimization Study." Report prepared for the World Bank with support from PPIAF.

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