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SYSTEM-SCALE PLANNING TO SUPPORT SUSTAINABLE ENERGY SYSTEMS AND CONSERVATION OF FRESHWATER RESOURCES FOR PEOPLE AND NATURE

Policy Briefs

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COVER PHOTO: WOMAN THROWING NET INTO WATER
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POLICY BRIEF 1: WHY IS IT IMPORTANT TO IDENTIFY HIGH CONSERVATION VALUE RIVERS IN NEPAL?

A *High Conservation Value River* (HCVR) is a **clean, highly connected** or **free flowing** river or stretch that acts as **a lifeline**, maintaining **ecosystem services** for present and future generations, providing **refuge** and **habitat** for high levels of **aquatic biodiversity**, and supporting important **socio-cultural values.** This definition was developed by Nepali experts and refined during a series of workshops and discussions over a year and a half.

Nepal is blessed with remarkable rivers supporting aquatic and terrestrial biodiversity, providing ecosystem functions like groundwater recharge and flood abatement, and offering socio-economic opportunity through livelihoods, recreation, tourism, natural beauty, and cultural identity. However, despite the country's historic leadership in creating protected areas from the mountains to the Terai, there are no specific policies and legislation that offer protection for the nation's rivers.

The USAID-funded Paani Program and WWF in collaboration with many stakeholders thus decided to undertake an HCVR assessment in Nepal, to:

- Highlight the increasing degradation of rivers in Nepal, and slow the loss of ecological, livelihood, cultural and other values
- Respond to the increasing calls to maintain portions of Nepal's river systems in a natural state
- Select baseline rivers for comparison against rivers which are being developed
- Identify rivers or river stretches that are still relatively intact and that are providing critical ecosystem services to nature and people
- Conserve the integrity of these rivers and river stretches for current and future generations

This is the first time that HCVRs have been identified and categorized in Nepal. The datasets and maps provide new insights into the location of high conservation value areas, both for individual indicators and for summarized levels of value. WWF and Paani worked alongside Nepalese experts from multiple organizations to identify and synthesize data for biodiversity, recreational, livelihood, and social and cultural values. The resulting national-level HCVR assessment is the first of its kind in Nepal and will be a key source of information for government agencies and other stakeholders.

Hydropower development is being proposed on all the major rivers across Nepal and is a significant threat to the diverse values of river systems. The HCVR maps show where those threats are most serious. For example, the high values of the main channel of the Karnali and its tributaries would conflict with several large-scale projects proposed for this basin. If these projects were developed, the impacts on the river ecosystem and its conservation values would be significant. The Karnali is one of the last free-flowing rivers in Nepal, with unique values such as providing a home for critically endangered dolphin and fish species such as Golden Mahseer and snow trout.

Identification of HCVRs provides critical information for planning at different levels through quantitative evaluation and spatial mapping of the values that rivers provide to

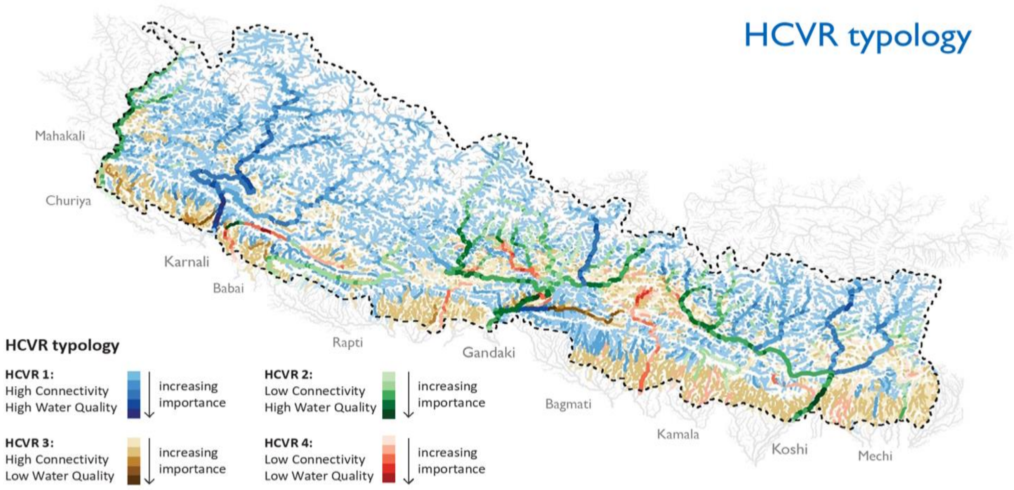


Figure: HCV Typology. The HCV typology combines the current freshwater status and the underlying values. The freshwater status refers to connectivity and quality pressures and is used to distinguish the four HCV types. Each type can have freshwater values ranging from low to high, indicated by the colour saturation. HCV Type 1 indicate rivers with the highest conservation priority, whereas other rivers have deteriorated river health but may still feature high conservation value.

society. Understanding where areas of high conservation value - i.e., those that support high levels of biodiversity, recreation, fisheries, or other socio-cultural values - occur within a country allows for more scientifically grounded decisions on river management. Natural resources managers and others involved with conservation efforts benefit from the identification of freshwater conservation priorities, which can guide decisions on where to focus their limited resources. Identification of HCVR can also guide hydropower development decisions, as illustrated by the system-scale planning tool developed through the Paani Program. For instance, under concepts of sustainable hydropower, the high social and environmental values of a free-flowing Karnali River should be balanced against the benefits of hydropower development. Developing projects in other locations may have lower impacts. The results from the HCVR assessment will contribute to a set of ongoing hydropower planning processes under the leadership of the Water and Energy Commission Secretariat (WECS), the apex agency of the Government of Nepal for water and energy policies and plans. These processes include a Hydropower Master Plan, River Basin Plans and Strategic Environmental and Social Assessments (SESA) for all river basins of Nepal.

Identification and ranking of Nepal's HCVRs can also help the country in meeting its national and international commitments. Nepal's National Biodiversity Strategy and Action Plan (2014-2020) and National Strategic Framework for Sustainable Development (2015-2030) prioritized maintaining north-south biological connectivity in at least three rivers. The HCVR results can be instrumental in supporting the identification of these rivers, preparation of the National Integrated River Basin Strategy and Action Plan by the Ministry of Forestry and Environment (MOFE), and associated legislation.

Finally, HCVR maps can provide insights into opportunities for mitigation of development impacts. Avoidance, minimization, restoration, and offsetting are options to mitigate the potential negative impacts of hydropower on river biodiversity and other values. Our results can provide quantitative assessment of rivers in which to avoid hydropower and other development and rivers to protect or restore, to compensate for impacts.

POLICY BRIEF 2: WHAT DO POSSIBLE LEAST-COST ENERGY FUTURES FOR NEPAL LOOK LIKE?

Decisions about future hydropower development must ensure that Nepal can meet its energy needs reliably, sustainably, and affordably. One of the components of the Paani-WWF cooperation therefore evaluated the country's options for power generation. Nepal currently has an installed capacity of 1,303 MW, almost all (97%) of which is from hydropower, and an electricity deficit which is partly met through imports from India. Large future increases in power demand are projected.

Hydropower development has suffered from extensive delays, and generation is dependent on the seasonality and variability of rainfall. Meeting demand reliably during the dry season with a hydropower-intensive system will produce a large surplus during the wet season. Most hydropower installations are run-of-river (RoR) plants, without storage capacity. Larger storage plants that require large capital investment have been left for the public sector, while independent power producers have focused on smaller and affordable RoR projects.

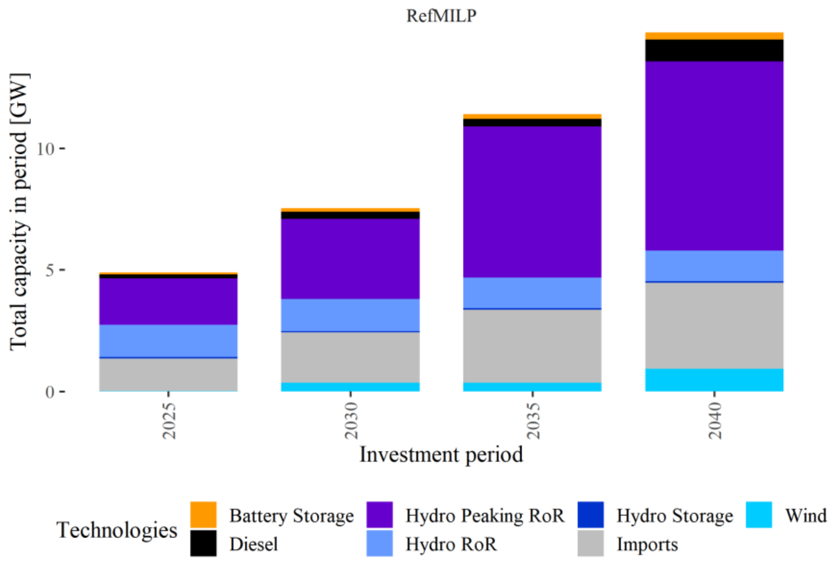
Other power technologies including wind, solar and batteries have become technically viable and cost-effective, and are growing globally at much faster rates than hydropower. Nepal currently generates only 2% of its total power supply from solar, and 0.12% from wind. There is significant scope for expanding the use of these renewables in the country. They can be built faster and have lower risks of cost overruns, because they rely on standardized components. Their modularity also allows development trajectories to match demand growth better than larger hydropower projects. They have lower impacts on the landscape and communities and can provide more local economic development opportunities. However, because solar and wind production is more variable than hydropower in the short term, they need to be combined with other technologies to balance power demand and supply.

Because today's investment decisions will determine the future mix of sources over decades, it is beneficial for countries to plan far ahead to ensure viable, least-cost, and low-impact combinations of technologies over time. Once these combinations are identified, governments need to direct investments into the right direction. This can be done, for example, through the Nepal Electricity Agency's (NEA's) purchasing decisions or decisions on spatial planning and environmental licensing.

Several power system expansion models are available to identify least-cost strategies for generation and transmission investment that meets future demand. We used the SWITCH model to find optimal investment portfolios, based on existing infrastructure, future costs and demand, hydrology, and available technologies (including all possible hydropower projects). The model simulates expansion of the power system in stages (2025, 2030, 2035, and 2040). As a least-cost model, outputs from SWITCH always satisfy both the policy interest of keeping power costs low for consumers, and the private investor's interest in selecting competitive projects. Additional policy objectives (for example, reducing imports to regain energy independence, investing equally in the different regions of the country, or protecting certain rivers from hydropower development) can be introduced into the model. SWITCH will still select the least-cost option that meets these constraints.

Expansion in an unconstrained base case or reference scenario is mostly based on peaking run-of-river (PROR) plants. By 2040, about 75%-80% of the annual energy is produced from hydropower, with the remaining 20%-25% supplied by a mix of imports and wind energy.

Annual imports are equal to exports. Wind is profitable from the first period, growing to almost 1 GW. The use of diesel plants is minimal, less than 0.1% of annual energy, but important during peak hours. Battery storage is deployed to provide alternative peak power starting in year 2025 with 80 MW, increasing to 300 MW by 2040 (see figure below).

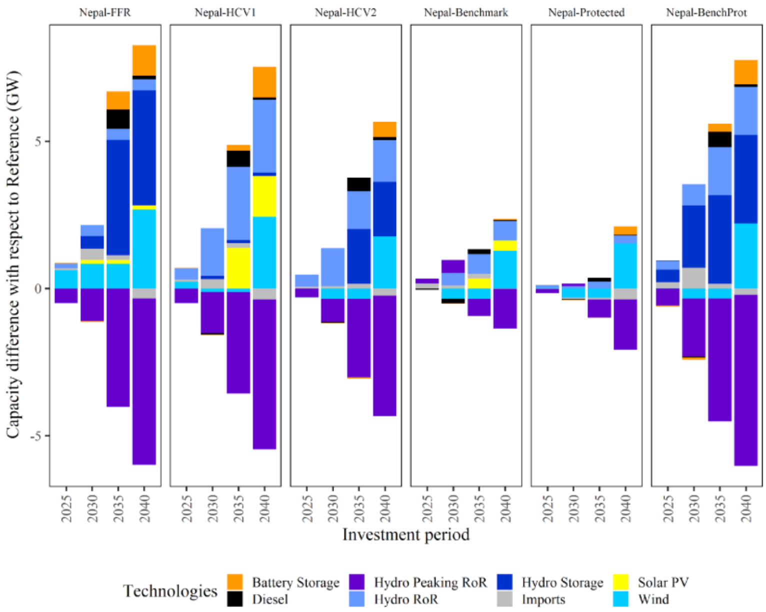


Capacity expansion for reference scenario

The model results suggest that Nepal has many options for river conservation with limited influence on power system cost. Different conservation scenarios (such as no projects on HCV or benchmark rivers, no projects in protected areas, or no projects in specific basins) result in different resource mixes (some of which are shown in the figure below), and in different system costs. For example, building no projects on the main stem Karnali or its major tributaries, or building no projects on any free-flowing rivers in Nepal, would increase system costs by 1% and 9% respectively. In their current configuration, protected areas in Nepal cannot sufficiently protect HCV Rivers from impacts of future hydropower development, because HCV Rivers are not sufficiently protected, and because dam development may occur upstream, or along protected areas. In some scenarios, the conservation constraints trigger higher adoption of other renewable resources such as wind and solar, while others tend to replace some hydropower projects with others that are still available.

Capacity mix difference between Nepal-wide conservation policy scenarios and the reference scenario

SWITCH can be used to compare many other scenarios and their combinations, and to test specific portfolios of projects that look promising. Our results show that Nepal could greatly benefit from more strategic decisions in the power sector, rather than leaving investment decisions to private investors who simply do not have the information to select the projects that are in the country's best long-term economic, environmental and social interest. Strategic selection of hydropower projects to reduce conservation impacts coupled with cost assessment tools like the



SWITCH model can enhance decision making. The affordability of scenarios with reduced hydropower capacity would be further improved if lower costs for solar photovoltaic (PV) – such as those expected for India – become available to Nepal. The technical report investigates in detail the impacts of different scenarios such as import curtailments, export-oriented development, the relative value of peaking RoR and batteries, and regional development policies.

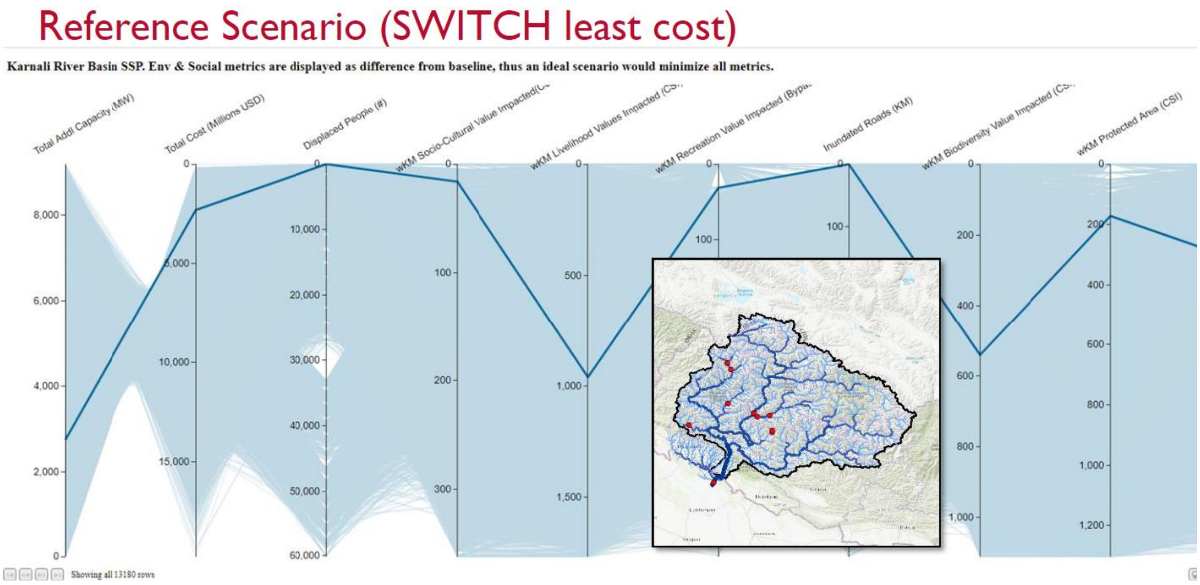
POLICY BRIEF 3: HOW CAN SYSTEM-SCALE PLANNING HELP NEPAL MAKE SMARTER CHOICES ABOUT HYDROPOWER GENERATION?

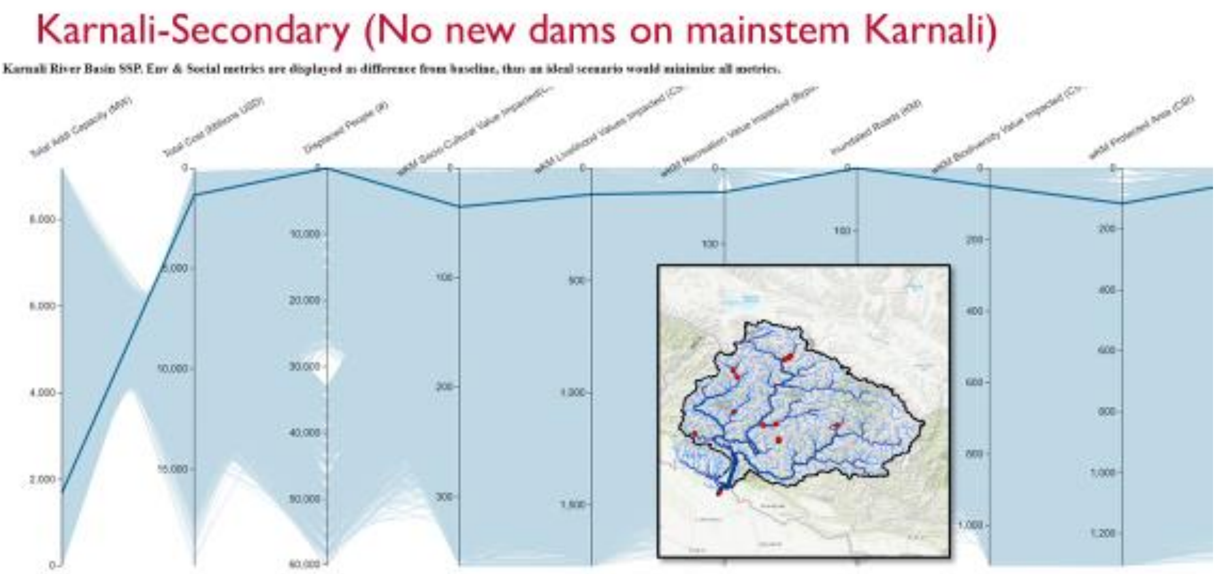
Nepal has abundant hydropower resources, only a small share of which will be needed over the coming decades. Many different combinations of projects could satisfy the power demand, even if the country should experience very rapid demand growth internally and from neighboring countries, while relying heavily on hydropower. Overdevelopment would bring unnecessary costs, low returns on investment, and a loss of ecosystem functions. Many nations have learned the hard lesson that restoration of degraded ecosystems is extremely costly. Nepal's opportunity lies in incorporating these lessons now and making informed choices, with a full understanding of the costs and benefits of different options.

One of the major strategic advances that Nepal can use is the ability to assess the cumulative impacts and benefits of multiple projects at a system level, rather than at the scale of single projects. System scale planning (SSP) is a quantitative, multi-criteria and multi-project framework. Its purpose is to support decision makers in making proactive decisions on the management of river basins, with an informed perspective of the tradeoffs between different development options. The SSP process evaluates how a combination of projects performs across a range of indicators or metrics that assess impacts on energy, financial and economic, environmental, and social values. The SSP process does this by combining the outputs from the High Conservation Value Rivers (HCVR) analysis, which indicates rivers with high levels of biodiversity, recreation, fisheries, or other socio-cultural values together with the lowest cost electricity development options that are an output of the SWITCH power system model.

SSP is run at a scale that is relevant for decision making, whether the river basin, electrical grid, or national scale. The data used in the modelling correspond with the scale of the analysis and do not require detailed site-specific information. SSP is not a replacement for site-specific studies but can inform such studies as well as investment and regulatory decisions by making project options comparable. One of the primary benefits of carrying out SSP at an early stage of national power development planning is the ability to select from a full suite of potential options. SSP is likely to result in better results compared to a development process in which individual projects are picked without full knowledge of how they compare to others, how they interact with others, and what their combined impacts and benefits are.

The intent of SSP, however, is not to provide one single answer that identifies the "best" hydropower development solution. A single best solution rarely exists: most options (combinations of projects) will have advantages but also disadvantages, compared to other options. SSP supports decision-making by quantifying these inevitable tradeoffs. One way to visualize tradeoffs is to compare different options and how they perform across several criteria, on so-called 'parallel axis plots' (see figure below). Each axis represents one criterion (e.g. total added capacity or km of river where livelihoods are impacted), with the most desirable outcome at the top. Hundreds of options, each represented by a line, can be compared based on where each line crosses the various axes. In the two charts below, two different options resulting from different SWITCH scenarios are highlighted by dark blue lines. Each scenario represents different projects (red dots in the map) that are developed in the Karnali basin. For instance, in the Reference Scenario (top), there are almost 1,000 km of river where livelihoods are impacted. In the Karnali-secondary scenario (bottom), the Karnali mainstem remains free-flowing, and there are less livelihoods impacted (e.g., the line is much closer to the top for the Livelihood axis, fifth from the left, compared to the Reference Scenario).





Outputs of the SSP analysis can help decision-makers including government agencies, developers, and financiers to identify combinations of projects that satisfy overall power demand at low costs and with low (environmental and social) impacts. Users can filter, identify, and explore combinations that meet their objectives (which could be quite different for a developer, an energy planner, a fishery official, or other stakeholders). The SSP process makes the tradeoffs visually clear and understandable. Knowing which combinations of projects are attractive in terms of costs and impacts can help the Government of Nepal in prioritizing their power generation decisions. As a more detailed process, SSP also works well at the provincial and basin level. Specifically, the outputs of SSP can support the prioritization of future hydropower investments, and the most immediate opportunity is to inform the ongoing Water and Energy Commission Secretariat (WECS) planning processes including the Strategic Environmental and Social Assessments (SESA).

POLICY BRIEF 4: HOW CAN THE OUTPUTS OF THIS PROJECT LINK INTO OTHER ENERGY AND WATER PLANNING PROCESSES IN NEPAL?

The three distinct components of the PAANI project 'System-scale Planning to Support Sustainable Energy in Nepal' support each other, and each of them supports specific planning processes in Nepal and can inform the positions of stakeholders or decisions of government leaders. However, the utility of these components is greatest when they are integrated. For instance, while the High Conservation Value Rivers (HCVR) assessment provides crucial information on priority rivers for conservation, combining HCVR with System Scale Planning (SSP) and the SWITCH Energy Options Assessment (EOA) can provide decision makers with a range of options for how conservation can be consistent with cost-competitive energy development. By incorporating and integrating the outputs from this project, Nepalese stakeholders and decision makers will have a more complete understanding of future options for energy development and conservation.

Categorization of rivers with high conservation value can contribute to Nepal's commitments to the Convention on Biodiversity (CBD). Understanding which rivers have been identified as HCVRs is based on objective, quantifiable criteria such as riverine and aquatic biodiversity, and the cultural, social, and economic value to communities. Those rivers that are critical for conservation can then be legally protected. According to the review of Nepal's commitments to the CBD, "freshwater ecosystems have so far have remained disregarded despite their significantly rich biodiversity hotspots and resources that make critical contributions to the livelihood and life support systems of Nepalese people". While such permanent protections are under preparation, options can be preserved through project-level decisions (e.g., on environmental licenses).

Understanding least-cost energy options for Nepal can support future power system planning. The Energy Options Assessment component of the project quantifies the costs of a range of scenarios that are designed to satisfy Nepal's future power demand. These scenarios are characterized by different technologies (including new technologies such as solar PV, wind, and battery storage), demand forecasts, assumptions on cost projections, and policy prescriptions and targets. The SWITCH model can be tasked with finding optimal investment portfolios, based on existing infrastructure, future costs and demand, hydrology, and available technologies (including all possible hydropower projects). The model simulates expansion of the power system in four stages (2025, 2030, 2035, and 2040). As a least-cost model, outputs from SWITCH always satisfy both the policy interest of keeping power costs low for consumers, and the private investor's interest in selecting competitive projects.[1]. By calculating the cost differences between alternative generation and transmission investments, Nepal can carry out improved power system forecasting and planning.

For any scale of hydropower development required, the system scale planning component can then help Nepal undertake more detailed analysis, to identify combinations of projects that have both low costs and low negative environmental or social impacts. The SSP process shows how outputs can be used to explore tradeoffs, make tradeoffs visually clear and understandable, and to search for a set of investment options (defined in terms of location, design and operation) that perform well across a range of economic, social and environmental objectives. Knowing which combinations of projects are attractive in terms of costs and impacts can help the Government of Nepal in prioritizing their power generation decisions. As a more detailed process, SSP also works well at the provincial and basin level.

[1] https://www.cbd.int/doc/world/np/np-nr-02-en.pdf

The integrated outputs of our project can support the prioritization of future hydropower investments, and the most immediate opportunity is to inform the ongoing planning processes of the Water and Energy Commission Secretariat (WECS). WECS is preparing a national hydropower masterplan and associated river basin plans, to revisit and prioritize all potential future hydropower projects, including those that already have licenses. In some cases, the masterplans will propose changing the location or the redesign of potential projects. The installation value and costs of all projects are estimated, which is a significant advance as there has previously not been any systematic information on comparative costs of these projects. The river basin plans also include other river-related developments, such as irrigation and flood control infrastructure, and will be subjected to Strategic Environmental and Social Assessments (SESA). The Paani-WWF initiative benefited greatly from the interim results of this process, allowing us to work with up-to-date project data. In turn, our initiative can inform the final formulation of the masterplan and the related reports. Besides the high level (national/provincial) usefulness in planning processes, the work also generated a number of spatial data layers related to water quantity, water quality, river classification, fisheries, biodiversity etc. that could be readily useful at local scales such as local government for conservation planning as well as spatial development planning. One of the ways these outputs can be used is that when Nepal introduces an auction or tender mechanism to select between the many projects offered by the private sector, the government will have the basis to decide which projects should be eligible in terms of location and technology.

Several lessons have been learned from this initiative:

- The utility of the SSP approach was improved by its integration with the other components. Basing an SSP analysis on detailed HCV assessments, and combining it with EOA analysis to demonstrate that preferred combinations of projects are viable and cost effective from an energy perspective, significantly increases the confidence in and the usefulness of the approach.

- The SSP analysis can be used to identify future low-impact hydropower portfolios and to assess the cumulative impacts of pre-defined portfolios. For example, it can inform the SESA assessments anticipated for WECS' river basin plans.

- The licenses granted to developers for the preparation of projects appear to add up to a larger capacity than is realistically cost-effective and needed, according to the EOA. Nepal could selectively cancel licenses or discourage developers of the least promising projects, in terms of costs and impacts. The SSP process could be used 'in reverse', to identify projects that are not represented in any of the preferred combinations and use this criterion to select projects for postponement or cancellation.

- Generation portfolios that rely heavily on hydropower carry greater climate change risk than those with more balanced generation mixes. This suggests that the government should remain open to a more diverse generation mix, especially if the costs of solar, wind and batteries should fall even faster than in our conservative assumptions.

- Overall, the EOA shows that very substantial protection of high conservation value rivers can be achieved with limited impacts on power costs. These cost impacts are significantly smaller than potential cost overruns from hydropower plant development. This is a positive result for river conservation, and shows that with the right framework, Nepal can have a robust and affordable power system and maintain the values of its river systems for future generations, at the same time. Implementing such strategic planning framework requires reforms such as mitigation requirements for projects, and proactive river protection policies at local, provincial, or national levels, but the payoff from such reforms will be substantial.

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