

EXECUTIVE SUMMARY

The Power of Rivers A Business Case

*How system-scale planning and management of hydropower
can yield economic, financial and environmental benefits*

Hydropower by Design can identify strategic and sustainable hydropower systems that deliver economic value to countries, financial value to developers, and greater environmental values from rivers.

KEY POINTS

- System-scale approaches to planning and managing hydropower—what we call Hydropower by Design (HbD)—can produce significant economic benefits for countries, while reducing environmental impacts, social conflict and investment risk.
- Through a series of case studies we demonstrate that Hydropower by Design can result in improved environmental performance for similar levels of energy generation, along with economic gains of 5 to more than 100 percent in other important river services.
- While the strategic planning required to achieve those balanced outcomes has often been equated with delayed implementation or associated with projects that are not financially attractive, we used in-depth financial and energy system modeling to show that the risk-management and engineering optimization benefits of Hydropower by Design can result in projects that are: one, financially competitive; and, two, strategic and low impact.
- In effect, the strategic economic and environmental benefits of system planning can be “paid for” by the financial benefits of Hydropower by Design. The potential global economic benefits of widespread adoption of Hydropower by Design are large: even a 5 percent improvement in other water-management resources in river basins where hydropower plays, or will play, a major role would produce up to US\$38 billion per year in benefits, a sum comparable to average annual investment in hydropower.

Hydropower will be an important contributor to low-carbon energy systems, representing nearly US\$2 trillion of investment between now and 2040. In river basins across the world, hydropower development and management will have potential positive and negative impacts on other uses of water resources valued at between US\$285 and US\$770 billion per year.

- To maintain the climate within safe boundaries, the world must rapidly decarbonize its energy systems, including a tripling of generation from low-carbon sources of electricity. Alongside the dramatic expansion of solar and wind, hydropower will likely remain a key technology, both to balance grids and to add capacity (Figure 1).
- Forecasts that assume the world meets its climate commitments suggest global hydropower capacity will increase by at least 50 percent by 2050, from 1,200 GW to approximately 2,000 GW (Figure 2). Based on average investment costs, this represents a total investment pool of US\$2 trillion. Asia will see the largest total increase, while Africa will experience the largest proportional increase.
- Hydropower development and management occurs in river basins with other diverse demands for water resources. Hydropower that is planned and operated as part of a larger system (such as a river basin, power grid, or jurisdiction) has the potential to increase the benefits from these resources. However, hydropower that is not considered part of a system will tend to miss out on opportunities to benefit other demands and can, at times, even conflict with them. Within hydropower-influenced basins (HIB) the total economic value of water-management services is very large (Figure 2), estimated to be between US\$285 and US\$770 billion per year:

© ERIKA GRIFFIN U. STROM THURMOND DAM RELEASE, SAVANNAH RIVER, GEORGIA, USA)



- 180 million hectares of irrigated land, providing between US\$100 and US\$410 billion in annual economic value.
- 660 million people and 145,000 square kilometers at risk of flooding within urban areas; annual flood damages within the HIB range from US\$20 to US\$40 billion and can be interpreted as the potential value of flood management.
- 88,000 million cubic meters (MCM) of reservoir storage for water supply, sufficient to support approximately 600 million people with drinking water, with an estimated economic value between US\$160 and US\$320 billion.

FIGURE 1

Projected increases in sources of low-carbon energy required to meet 2040 climate objectives, at which point renewables would represent over half of electricity generation.¹

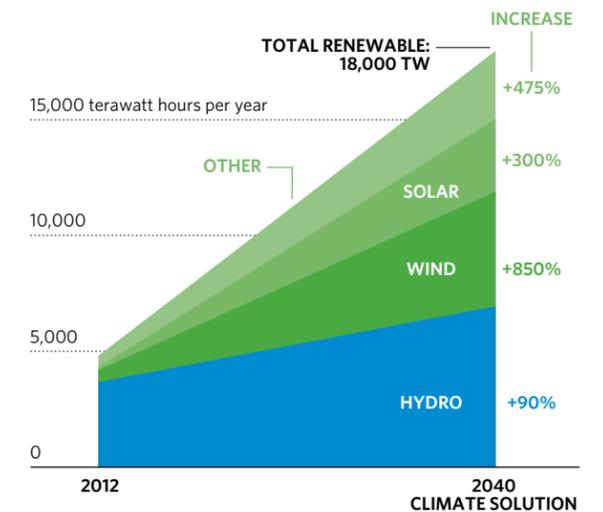
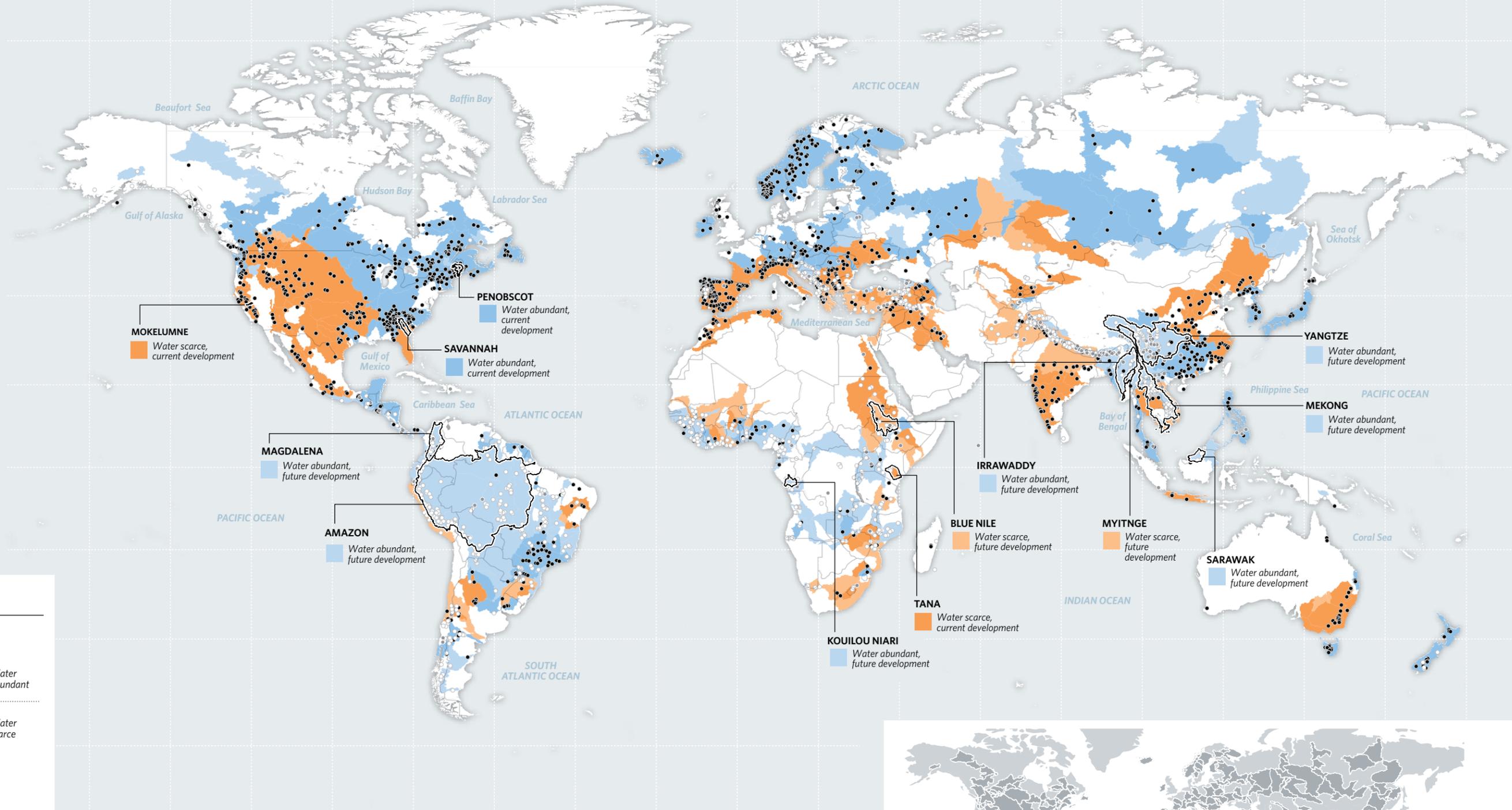


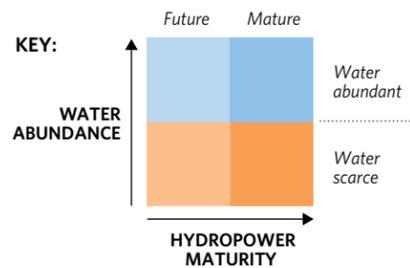
FIGURE 2

Hydropower influenced basins; blue shading indicates those with abundant water; dark blue are "mature" in terms of development ("current development") and light blue have most development in the future. Orange shading indicates area where water is more scarce; dark orange are "mature" ("current development") and light orange have development in the future. Solid dots are existing hydropower dams, gray dots are hydropower dams under construction and open circles are planned or potential hydropower dams. Case study basins are highlighted.

The bar charts in the lower left reflect levels of water supply storage, people at risk of flooding in urban areas, and hectares of land irrigated by surface water compared across the four types of hydropower influenced basins ("future" = "future development"; "current" = "current development"; "abundant" = "water abundant"; "scarce" = "water scarce").

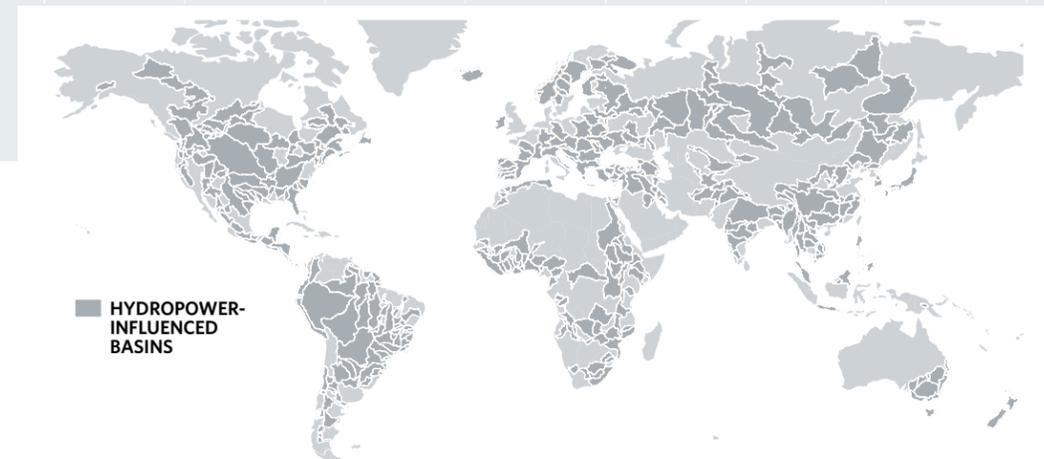


CATEGORIES OF BASINS



BASIN TYPE	WATER SUPPLY STORAGE (MCM)	FLOOD RISK (MILLION OF PERSONS)	IRRIGATED LAND (HA)
FUTURE ABUNDANT	888	70	16
MATURE ABUNDANT	42,317	238	22
FUTURE SCARCE	6,531	97	53
MATURE SCARCE	38,157	256	88

- EXISTING HYDROPOWER DAM
- UNDER CONSTRUCTION
- PLANNED





© MICHAEL YAMASHITA (DALAH MARKET, MYANMAR)

However, this expansion of hydropower must be done right. If planned in isolation (e.g., at the project scale and/or without incorporating objectives for those other resources) hydropower projects will generally fail to achieve their full potential for providing multiple benefits. They could, in fact, cause significant negative impacts on more than 300,000 kilometers of rivers and their associated environmental and social values.

- Development based strictly on single-project financial criteria can result in hydropower projects that provide generation but do not contribute to broader energy goals—such as integrating intermittent renewables onto the grid—and, by occupying an advantageous site, can even make it harder to achieve those goals.
- Poorly planned hydropower, along with missed opportunities to achieve broader benefits, have contributed to social conflicts around hydropower development and operation. For existing projects, conflicts can lead to litigation and compulsory retrofits or changes to operation. For projects in the planning or construction stages, conflicts can contribute to delays, cost overruns and cancellations. Hydropower projects are often large, complicated projects that are very site specific and thus a wide range of factors can contribute to these problems. However, social and environmental conflicts can be major factors and the significant impacts of some hydropower no doubt contribute to the fact that hydropower projects have higher delays and overruns compared to other large infrastructure projects. These, in turn, contribute to perceptions of risk and uncertainty that can affect the flow of investment. High-profile recent examples of delayed, suspended or cancelled projects—including Myitsone (Myanmar), HidroAysen (Chile), Sao Luis do Tapajos (Brazil) and Belo Monte (Brazil)—provide compelling examples of how incomplete consideration of environmental and social impacts during planning and site selection can lead to significant challenges to developers and investors. The first three of these projects represent an aggregate of US\$1.3 billion in stranded investment and 18 GW of undeveloped capacity.

- The environmental and social costs of this expansion of hydropower could be enormous. Negative impacts on ecosystems and people from hydropower are well-documented through both actual and modeled outcomes, such as a projected 40 to 60 percent decline in migratory fish biomass in the Mekong River basin from full development of mainstem dams. Within high-income countries, dams are already a leading cause of extinction of freshwater species and the decline of freshwater ecosystem services. The projected levels of development of new hydropower, largely in lower- and middle-income countries, could impact more than 300,000 kilometers of free-flowing rivers, with the majority of those impacts occurring in rivers that provide the greatest benefits to rural communities through food production and livelihoods. For example, river basins with the most projected expansion of hydropower currently support at least 6 million tons of fish harvest, enough to be the primary source of animal protein for 130 million people.

Governments confront an apparent dilemma: system-scale planning and management can reduce these negative environmental and social impacts and ensure that hydropower achieves its full potential contribution to a country's strategic objectives for energy and water, but governments often believe that system-scale planning is associated with implementation delays and projects that are less attractive financially.

- Strategic planning has often been equated with long and cumbersome processes and a government may be concerned that this approach will identify projects and management options that are in the country's strategic interest, but which are not financially attractive to developers and investors, inhibiting the flow of investment to meet development needs. From this viewpoint, selecting strategic development pathways would come at a cost of delaying or inhibiting investment.
- On the other hand, projects selected primarily due to financial attractiveness to developers may encourage investment, but result in projects with higher impacts and that contribute less effectively to broader strategic goals, such as economic value.
- What's needed are processes and tools that can identify development and management options that are: one, strategic and low impact; and, two, financially competitive.

2 Migratory fish represent the most important part of the current fishery, valued at US\$11 billion per year and the primary source of protein and livelihood for tens of millions of people.
3 Note that freshwater fish harvests are generally under-reported, so the actual totals are likely considerably higher.

Hydropower by Design can be broadly defined as a comprehensive and system-scale approach to hydropower planning and management that fully integrates other sectors and environmental and social issues from the earliest stages to promote sustainability and optimize delivery of benefits.

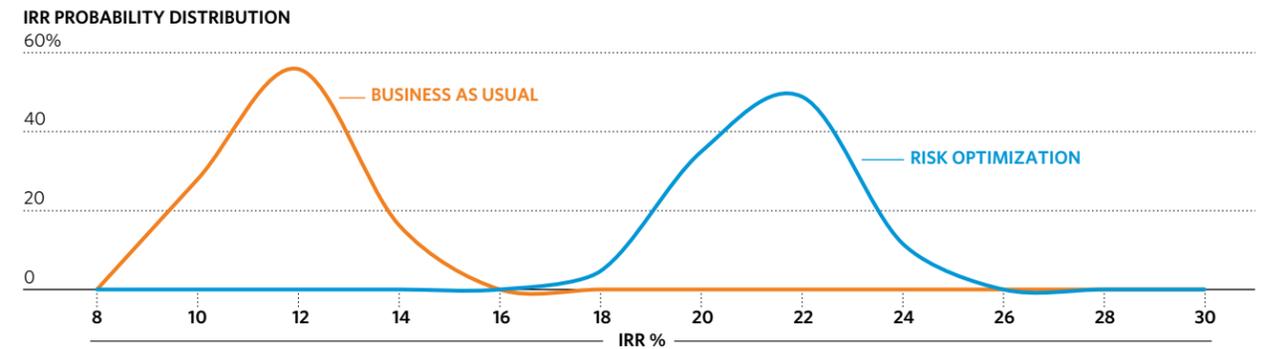
Hydropower by Design’s integration of perspectives and models makes it possible to capture two key sources of financial value: one, system design optimization; and, two, improved risk management to reduce delays and cost overruns due to environmental and social impacts. Hydropower by Design (HbD) can identify portfolios of projects that have superior Internal Rate of Return (IRR) values. These superior returns can “pay for” economic, social or environmental objectives. Through the application of HbD—which generates a pipeline of strategically compatible projects that also have competitive IRRs—countries can afford to be strategic.

- Hydropower is often developed through a set of disconnected project-level decisions. The single-project approach misses opportunities to capitalize on system-scale financial value because each individual project, built to meet expectations of a single developer, changes the physical context in the basin (e.g., flows, transmission lines and other infrastructure) for all future development opportunities. The HbD approach to project selection—guided by the integration of water-management, environmental, energy and financial models—embeds decisions about individual projects within a system optimization, identifying a set of projects that capture system-level financial efficiencies. This results in a portfolio of individual projects with greater average financial performance than project-by-project, “business as usual” (BaU) approaches.

- A second source of financial value compared to BaU arises through improved identification and management of risks, which can inform site selection and design and contribute to reduced conflicts, cost overruns and time delays due to environmental and social impacts. Delays can cause significant reductions in projects’ IRR, as each month a project is delayed is a month of additional expenditures and foregone revenues. By bringing water resource management and ecosystem models into the selection and design process for new projects, project risks can be assessed more realistically and risk projections can be incorporated into investment return models. This results in a portfolio of projects with lower risks, improving the distribution of projects’ IRR compared to the BaU approach.
- By capturing these sources of financial benefit, projects selected under a Hydropower by Design approach in a case study from Colombia could meet energy objectives with 66 percent less social impact and 5 percent fewer environmental impacts when compared to a BAU approach, while at the same time achieving a greater average IRR (22 percent versus 13 percent; Figure 3) and a superior NPV (\$5.3bn versus \$2.4bn).

FIGURE 3

A comparison of the modeled distribution of Internal Rate of Return (IRR) for a set of individual projects selected through Hydropower by Design (“risk optimization”) and through Business as Usual approaches for the Magdalena River in Colombia.



© TIM LAMAN/NATIONAL GEOGRAPHIC CREATIVE (LAMBIR HILLS NATIONAL PARK, SARAWAK RIVER, MALAYSIA)



Hydropower by Design (HbD) can identify options that provide similar levels of generation as business-as-usual (BaU) approaches, but do so with lower environmental impacts and achieve improvements from 5 percent to more than 100 percent for other water management values, such as irrigation and migratory fish habitat.

- Hydropower by Design offers the potential for broad economic benefits to countries. In a set of modeled case studies, HbD approaches to planning and management were able to increase the level of other economic values by 5 percent to more than 100 percent compared to BaU, generally with no or limited reduction in energy generation and, in some cases, an increase in generation. In basins where water is scarce and reservoirs tend to have multiple purposes, these other economic values included irrigation, water supply, flood management and floodplain livestock. Within basins where water is abundant, hydropower dams are often single purpose, though flood management and water supply were also improved in some of these basins. In nearly all of the basins, environmental performance could be improved (Figure 4). These improvements are highly basin-specific due to the complicated nature of interacting economic, social, infrastructure and biophysical systems.
- For many resources, larger improvements are possible when Hydropower by Design is implemented at the planning stage and can influence site selection.
- River basins are inherently complex with site-specific combinations of resources, constraints and opportunities. For example, while performance for some resources may be positively correlated in one basin, they may be negatively correlated in another. Thus, extrapolating from a set of case studies to a global perspective confronts substantial challenges. Nevertheless, it is instructive to consider the potential global scope of improved economic performance that could arise from widespread use of Hydropower by Design. For example, if system-scale approaches to hydropower planning and management could achieve a net improvement of even 5 percent in other water management services, then that would result in increased global

economic value of approximately US\$14 to US\$38 billion per year, a number that is comparable to average annual investment in hydropower. This underscores that countries and development organizations should be motivated to promote the planning, decision-making, financing and regulatory processes necessary to secure these potential gains. The realization that greater than 5 percent improvement may be possible in many areas should further motivate implementation.

The Way Forward: Hydropower by Design can be implemented in ways that are practical, affordable and timely.

- Through new modeling tools and a process that bring together diverse objectives, data sources and families of models, Hydropower by Design can deliver useful insights about development and management options in a relatively short period of time. Rather than delaying decisions or investments, these system-level tools and approaches may reduce project-level uncertainty and delay, thereby reducing investment risk.
- Hydropower by Design is not an entirely new process, but rather its principles and tools can be integrated into existing planning and regulatory processes, ranging from generation options assessments to basin master plans or strategic environmental assessments.

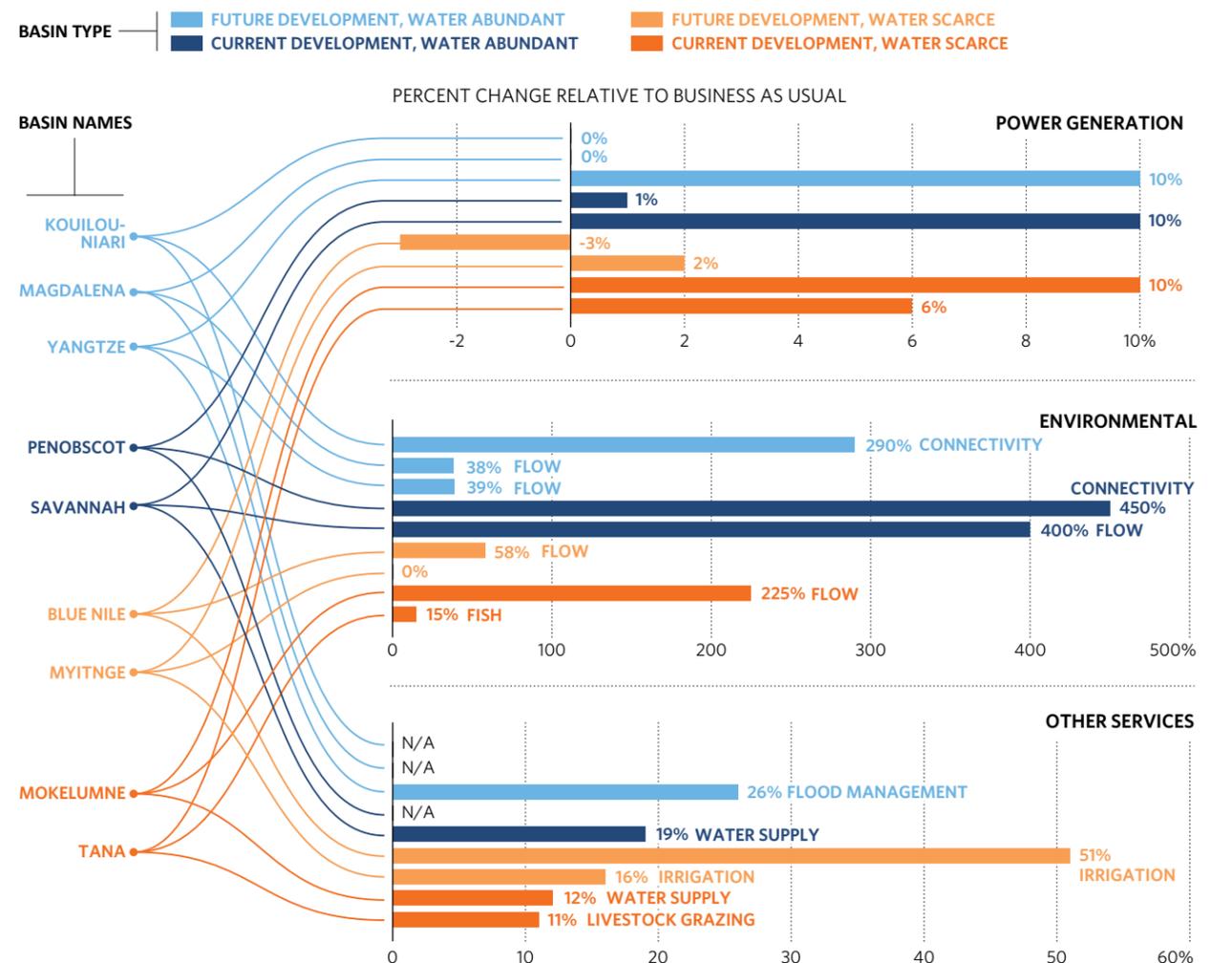
A number of mechanisms can be used to promote the system planning and balanced outcomes described in this report:

- A project preparation facility that: one, includes upstream planning capabilities to help governments select project sites based on system-scale HbD principles; and then, two, prepares the sites with midstream project preparation work. This type of facility could assist development banks' access to a high-quality pipeline of pre-selected, bankable projects that also meet the host country's broader strategic objectives.

- Based on a strategic planning process, governments can use auctions to identify developers for pre-selected strategic projects, making those projects more attractive by offering access to power purchase agreements, payments for firm energy, or guaranteed feed-in tariffs.
- Access to development bank loans, green bonds and other preferential sources of capital can be made easier for projects selected through a strategic planning process.
- Environmental agencies can incorporate the mitigation hierarchy into environmental review, licensing processes and mitigation requirements. Additionally, the permitting process for pre-selected projects can be fast-tracked, as there will be more comprehensive information available on the project and system objectives at an early stage.

FIGURE 4

Economic and environmental improvement possible through application of Hydropower by Design in case studies from nine river basins. In each case, a Hydropower by Design (HbD) scenario was compared to a Business as Usual (BaU) scenario with comparable financial cost and/or comparable economic cost. Basins were categorized based on their development status (current or future) and water availability (abundant or scarce).



*Hydropower by Design
can identify strategic and
sustainable hydropower
systems that deliver economic
value to countries, financial
value to developers, and
greater environmental
values from rivers.*



About The Nature Conservancy

The Nature Conservancy's water program is backed by 400 staff working across more than 500 freshwater conservation projects around the world. We use science, innovation and collaboration to meet the global challenges facing rivers today. By providing strategic guidance on hydropower planning, downstream flows and other solutions to protect and restore rivers, we have collaborated on conservation or restoration solutions with industry, governments and other stakeholders.

For more information visit: [nature.org/powerofrivers](https://www.nature.org/powerofrivers)

