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# CONNECTED & FLOWING



**A RENEWABLE  
FUTURE FOR RIVERS,  
CLIMATE AND  
PEOPLE**

# EXECUTIVE SUMMARY

Due to the renewable revolution, power systems can now be low carbon, low cost, and low impact on rivers, the environment and people

The world faces multiple critical and intertwined challenges: expanding electricity generation to meet the needs of growing economies and to supply power to the more than one billion people who currently lack access while reducing greenhouse gas emissions to nearly zero by 2050 – all while maintaining the integrity of our world’s ecosystems, including conserving the planet’s remaining free-flowing rivers.

Today, the world has a great opportunity to solve these challenges, made possible by the renewable revolution — featuring rapidly falling costs for wind and solar generation and storage technologies, and significant advancements in energy efficiency, demand side management, and grid management. In addition, great progress has been made on the accessibility of tools that allow governments to strategically plan power systems so that the expansion and operation of projects can maximize synergies and minimize negative impacts.

We can now envision a future in which electricity systems are accessible, affordable and powering economies with a more sustainable mix of renewable energy technologies — including solar, wind,

storage and low-impact hydropower. For the first time, there are viable renewable alternatives to the high-impact hydropower dams that are currently proposed on many of the world’s remaining free-flowing rivers – a development path that could trigger a range of negative impacts, including displacement of communities, and the loss of productive freshwater fisheries and much of the sediment needed to keep economically crucial deltas above the rising seas.

This report describes how the world can tackle these intertwined challenges and support global efforts to achieve the Sustainable Development Goals (SDGs) and the targets under the Paris Agreement, by moving rapidly toward electricity systems that are:

**1. Low carbon.** The imperative to decarbonize energy systems, and economies in general, becomes increasingly clear with each passing year. A stable climate – and prosperous societies and healthy ecosystems – requires that electricity systems move rapidly to being low carbon and efficient and that some sectors, such as heating and transportation, be electrified.

**2. Low cost.** Power systems that are low carbon and low impact must also meet countries’ power demands with electricity that is reliable and affordable. Furthermore, social equity demands that energy investments ensure access to the more than one billion people that still lack access to reliable electricity. In fact, the short construction times, versatility, and low costs of new renewables allow countries to accelerate access to electricity.

**3. Low impact.** Nearly all options for producing energy have some negative impacts on communities and the environment. But, options for low-impact systems are becoming increasingly feasible and various best practices can be applied to further reduce impacts, particularly on the world’s remaining free flowing rivers.

Achieving this vision will not happen by pre-judging what technologies and mixes of energy generation should be deployed. Decisions about future electricity systems should follow a process to identify options that are consistent with the principles above. Any mix of sources that can meet those principles (low cost, low carbon and low impact) will work for people, nature and the climate.

In practice, we believe that electricity systems that meet these principles will increasingly be those that avoid the significant tradeoffs associated with high-impact hydropower projects. However, avoiding those tradeoffs and impacts does not equate to an end to hydropower development, but to a significant shift in its role and competitive niche. Hydropower projects provide a range of services that can help balance power systems and facilitate the integration of a higher share of wind and solar generation — both through the reoperation of existing hydropower and through strategically designed new projects, including off-channel pumped storage, that avoid the significant tradeoffs associated with past development. These carefully planned projects will provide lower risk and higher value to investors and developers, while delivering greater overall values to countries and communities.

## The urgent need to expand access to energy while decarbonizing power systems

To avoid exceeding a global temperature rise above 1.5°C, the IPCC reports that the world will need to cut global CO<sub>2</sub> emissions by approximately 40-50%

## KEY POINTS

- The costs of wind, solar, and battery storage have dropped dramatically in recent years – and are continuing to fall. Renewable sources represented two-thirds of new global power generation capacity in 2018, led by wind and solar.
- The global technical potential of utility-scale, low-impact wind and solar is 17 times the renewable energy targets that countries have committed to under the Paris Agreement, and well distributed. This should allow almost all countries to achieve power systems that are low carbon, low cost, and low impact on social and environmental resources.
- Lowering the total number of new hydropower dams because of greater investment in wind and solar can reduce negative impacts on rivers and avoid fragmenting tens to hundreds of thousands of kilometers of free-flowing rivers globally, depending on how development unfolds within river basins.
- Planning tools that integrate capacity expansion models with models to guide low-impact siting of new renewables can help decision makers design systems that are low carbon, low cost and low impact.
- The renewable energy revolution does not signal an end to hydropower development, but a significant shift in its role. Certain types of hydropower are becoming less competitive and the rise of reliable alternatives should diminish the need for high-impact dams. However, low-impact hydropower plants, which provide storage capabilities and flexibility, could become an important component of the world's transition to deploying considerably more intermittent renewable energies.
- By capitalizing on economic and financial trends as well as improved technologies, we can secure a brighter future for people and nature with power systems that are low carbon, low cost and low impact on rivers and other ecosystems.

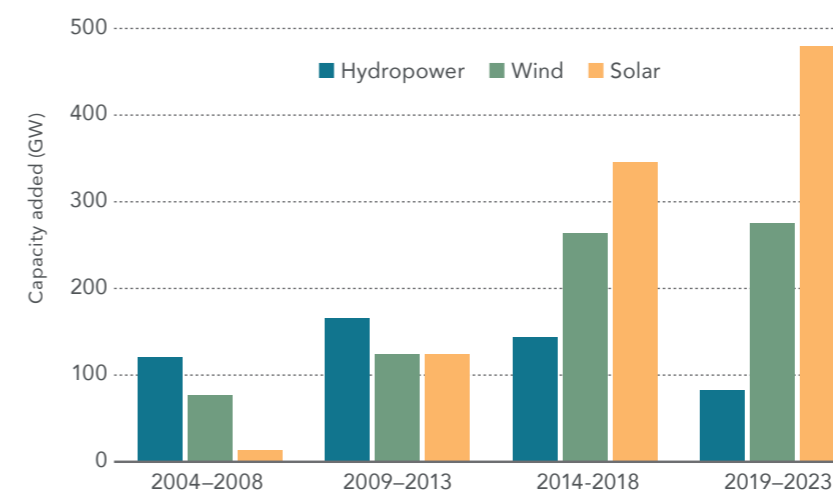
by 2030 and economies will need to become nearly carbon free by 2050. Since electricity generation is a leading source of GHG emissions, decarbonization of power systems is critical to achieve the necessary emissions reductions, especially as electricity generation must increase to provide power to the more than one billion people around the world who still lack access. This will require a rapid transition away from fossil fuels (coal, natural gas and oil) to low-carbon renewables such as wind, solar, geothermal and hydropower. While hydropower has been the dominant source of renewable generation so far, projections of how the world can meet future electricity demand while also achieving climate goals include a massive increase in the proportion of wind and solar, with these sources expected to attain a share of generation comparable to, or exceeding, that of hydropower.

### The renewable revolution is rapidly changing the landscape of power systems

The costs for a range of renewable energy sources have dropped dramatically in the past decade. Costs for solar and wind are now approaching US\$0.05/kWh – comparable to the low end of fossil fuel cost range and the average costs of hydropower.<sup>1</sup> And costs are projected to decline even further.

Because of these rapid changes in relative costs in recent years, the growth of power generation is now driven by investments in new solar and wind capacity (Figure 1). Capacity additions of hydropower have been declining since 2013, due not only to the falling costs of competing technologies, but also to a broader set of challenges, including high-profile cancellations, growing hydrological risks, cost and schedule over-runs, technical challenges, and increasing social resistance.

Certain types of hydropower are becoming less competitive, with the rise of reliable alternatives diminishing the need for high-impact dams. However, low-impact hydropower plants that provide storage capabilities and flexibility have a strong role to play in backing up variable sources, such as solar and wind, and providing the ancillary services that contribute to grid stability. Low impact hydropower could still be an important component of the world's transition to deploying considerably more intermittent renewable energies.



### 1. Recent growth in renewables by type

Global renewable power capacity additions, 2004-2023 (from IEA 2017).<sup>2</sup>

### The renewable revolution can increase conservation of free-flowing rivers by delivering low cost, low carbon, low impact grids

Projections vary widely of how much hydropower will be developed to meet the 2050 power demand and achieve climate objectives. For example, from a current capacity baseline of approximately 1,200 GW, IPCC scenarios that limit global temperatures to below a rise of 1.5°C have median 2050 projection for global hydropower of 1,820 GW – a level that would result in an additional 190,000 kilometers of river channel being impacted by fragmentation, with more than 70% of the impact occurring in river basins with the greatest fish harvest and the highest richness of fish species<sup>3</sup>.

However, the trends in cost and levels of investment for hydropower compared to other renewable technologies, and the potential to retrofit existing dams and re-operate cascades — along with lower projections for hydropower in 2050 such as that of Teske (1,523 GW)<sup>4</sup> — suggest that future hydropower development may be lower. A lower level of development could reduce impacts by 65,000 km. With strategic system planning, impacts could be reduced a further 100,000 km - in total, a nearly 90% reduction in impact on river fragmentation (Figure 2) – securing the diverse benefits that healthy rivers provide to people and nature.

The ability to substitute wind and solar for a portion of hydropower development hinges on the improving competitiveness of those technologies and the ability of grids to incorporate high levels of variable

renewable energy, described in case studies below. But ensuring that this substitution leads to electricity systems that are as low impact as possible requires the widespread availability of wind and solar power in areas with low impacts on social and environmental resources. The global technical potential of low-impact utility-scale wind and solar (on converted lands such as agriculture, degraded land, and rooftops) is 17 times the renewable energy targets that countries have committed to under the Paris Agreement, and well distributed (Figure 3)<sup>5</sup>. This should allow almost all countries to achieve power systems that are low carbon, low cost, and low impact.

#### Case studies of low carbon, low cost and low impact grids

A number of recent studies have demonstrated the economic and technical feasibility of grids that are low carbon with expansion dominated by renewables. We further explored the potential of low cost, low carbon grids to be low impact on rivers by integrating capacity expansion models for two countries, Chile and Uganda, with basic landscape modeling of the environmental values of rivers.

- In Uganda, a scenario that avoided future hydropower dams within national parks had no impacts on power system costs compared to the reference, or business as usual (BAU), scenario; solar PV and storage would replace the two hydropower plants within a national park that are selected in the reference scenario.
- In Chile, the reference (BAU) scenario included both coal and a significant expansion of

## 2. Hydropower expansion and impact on rivers

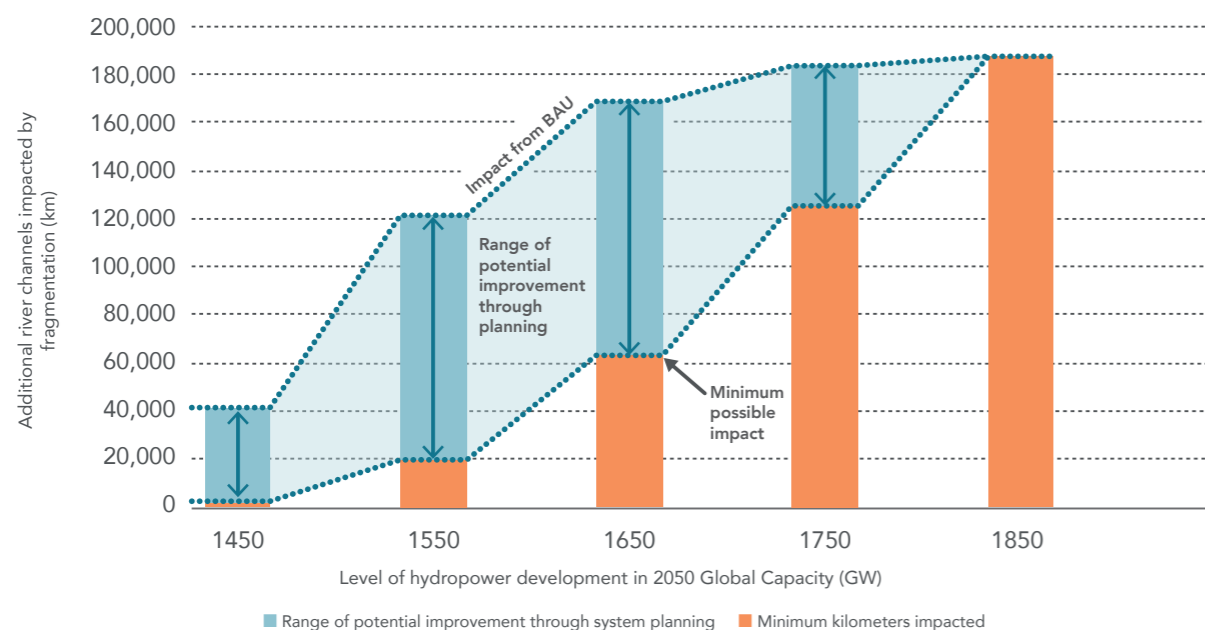


Figure 2. Potential improved outcomes for global rivers through substitution of other technologies for hydropower (moving from right to left) and through system planning to optimize between generation and environmental performance within river basins (blue shaded area within any given level of development). The top of the combined bar represents the level of impact from business-as-usual development of hydropower dams for a given total level of global hydropower capacity by 2050 and the top of the red bar represents the minimum impact possible at that level of development<sup>i</sup> (From Opperman et al. 2015 based on dam database from Zarfl et al. 2015)<sup>6</sup>.

hydropower. Low carbon scenarios that also avoided developing new dams on Chile's remaining free-flowing rivers had costs that were only 1.5–2% higher than the reference scenario, with a carbon intensity that was one-quarter that of the reference scenario.

These examples demonstrate how the integration of capacity expansion models with landscape models to guide siting can reduce the impacts from hydropower within power systems. A range of other best practices can be used to further minimize impacts from hydropower generation, including rehabilitating and retrofitting existing hydropower dams, re-operating dams and cascades, and adding turbines to non-powered dams. Overall, incorporation of the mitigation hierarchy into regional planning for new renewable projects can reduce

impacts and conflicts, contributing to conservation and facilitating faster permitting and development.

### What the world needs to do to achieve the low carbon, low cost and low impact vision

Accelerating the renewables transition requires the removal of barriers, including policy and regulatory reforms, redirecting financial flows towards new renewables, and technological innovation. There are successful examples for all of these that can be emulated by other countries. Many governments need to modernize their energy-sector policies to take full advantage of the renewable revolution, for example by committing to renewable energy targets and/or introducing targeted auctions for renewables to identify least-cost options.

Financing of new renewables not only needs to be scaled up dramatically, it also needs to include funding for system planning, via both domestic budgets but also through support from international financial institutions. The integration of capacity expansion models with models to guide siting of new renewables can help decision makers understand tradeoffs of different options and identify those options that perform well across a range of objectives (see Box 1).

### BOX 1

## SUSTAINABLE POWER SYSTEMS FOR THE MEKONG RIVER BASIN

The Mekong River supports the world's most productive freshwater fishery and delivers sediments that maintain the physical integrity and productive ecosystems of the Mekong Delta, a crucial part of Vietnam's economy and regional food security, and home to 21 million people.

Hydropower has been a primary source of electricity for Mekong countries, but studies show that a continuation of the current hydropower trajectory would cause the loss of nearly half of migratory fish biomass. Deprived of sediment trapped behind dams and subject to other pressures, the delta could be more than half underwater by the end of this century.

Recent studies suggest that the region could meet future power demand with considerably lower development of hydropower than

business-as-usual projections. The integration of capacity expansion models with models to guide low-impact hydropower siting provided strong evidence that the Mekong region can develop low carbon, low cost power systems that do not require dams on the mainstem or on the few remaining free-flowing major tributaries – and that any additional hydropower can be sited so as to have minimal impact on fisheries and sediment per unit of hydropower produced.

Although there are signs that the renewable revolution is taking hold in the Mekong region, decisions in the next few years on highly impactful dams such as Sambor could preclude more balanced outcomes. Coordinated and proactive policies and planning are needed to ensure that countries pursue a more sustainable energy path.

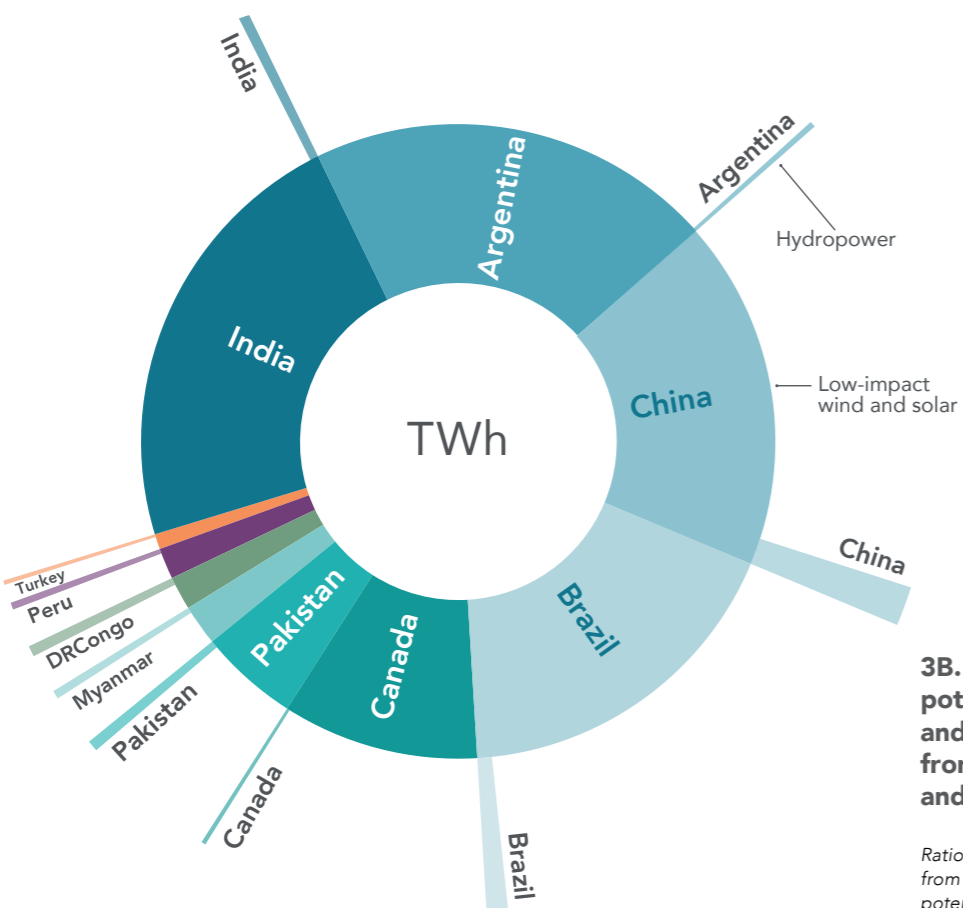


Adam Oswell / WWF - Greater Mekong

<sup>i</sup> Note that the bar for 1,850 GW is depicted as having no range of potential improvement from system planning, but that is because that level of development requires building all the dams in the database and thus we can't model different configurations

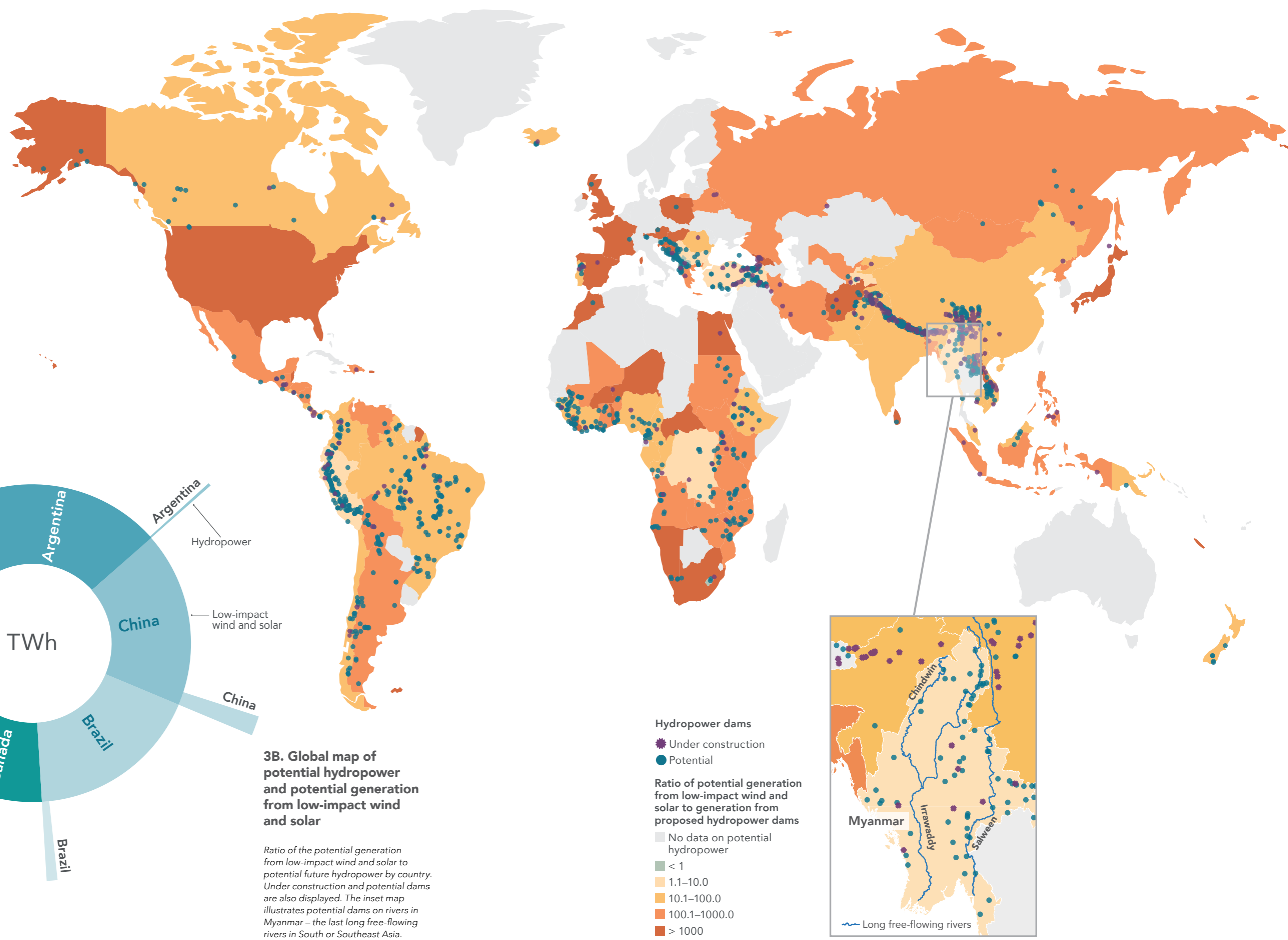
**3A. Potential generation by country: hydropower and low-impact wind and solar**

Potential generation, in TWh, from low-impact wind and solar (inner ring, from Baruch-Mordo et al. 2019) and potential future hydropower (outer ring, from Zarfl et al. 2015). For scale, for India the potential generation from low-impact wind and solar is 8,485 TWh and from hydropower is 139 TWh<sup>7</sup>.



**3B. Global map of potential hydropower and potential generation from low-impact wind and solar**

Ratio of the potential generation from low-impact wind and solar to potential future hydropower by country. Under construction and potential dams are also displayed. The inset map illustrates potential dams on rivers in Myanmar – the last long free-flowing rivers in South or Southeast Asia.



## CONCLUSION

Within a very short time, the vision of low-cost, low-carbon, and low-impact power systems has become a real possibility. Much of the renewable energy revolution is already underway. Although this transition received some initial momentum from policies, it is now driven as much by technological innovation and marketplace competition as by policy<sup>8</sup>.

We can not only envision a future where electricity systems are accessible, affordable and powering economies with a mix of renewable energy technologies — including solar, wind, storage and low-impact hydropower—we can now build that future. Growing electricity demands and climate objectives can be achieved while avoiding the negative impacts on the world’s remaining free-flowing rivers posed by high-impact hydropower.

Achieving the vision will require policy, financial, and technical innovations across all countries. Fortunately, at this stage the feasibility of low-carbon, low-cost and low-impact systems — and the benefits of achieving them — are becoming clear, creating powerful incentives for different groups of stakeholders (see Box 2). These stakeholders need to take proactive and collaborative action to ensure a rapid transition to more sustainable power systems. If various constraints delay the transition by even a decade, the health and productivity of rivers such as the Mekong, Irrawaddy, and Amazon — and dozens or hundreds of others around the world — will decline due to significant impacts that are both near-permanent and avoidable. It would be a great tragedy if the full environmental benefits of the renewable revolution arrived just a few years too late to safeguard the world’s great rivers and all the diverse benefits they provide to people and nature.

To avoid those losses — and seize the profound opportunity before us — we hope this report serves as a call to action for collaborative acceleration: working together, governments, financial institutions, the private sector, civil society and scientists can build the tools and mechanisms necessary to catalyze rapid delivery of a more sustainable energy future for the climate, rivers and people.

### ENDNOTES

- <sup>1</sup> IRENA (2019): “Renewable Capacity Statistics 2019.” International Renewable Energy Agency (IRENA), Abu Dhabi. Retrieved from: <https://www.irena.org/publications/2019/Mar/Capacity-Statistics-2019>
- <sup>2</sup> IEA (2017): “Solar leads the charge in another record year for renewables.” Retrieved from: <https://www.iea.org/renewables2017/>
- <sup>3</sup> Opperman, J., Grill, G. and Hartmann, J., (2015). *The Power of Rivers: Finding balance between energy and conservation in hydropower development*. Washington, DC: The Nature Conservancy.
- <sup>4</sup> Teske, Sven., (2019): *Achieving the Paris Climate Agreement Goals*. Springer.
- <sup>5</sup> Baruch-Mordo, S., Kiesecker, J., Kennedy, C.M., Oakleaf, J.R. and Opperman, J.J., (2019): From Paris to practice: sustainable implementation of renewable energy goals. *Environmental Research Letters*.
- <sup>6</sup> Opperman et al. 2015 (see note 3); Zarfl, Christiane, Alexander Lumsdon, Jürgen Berlekamp (2015): A global boom in hydropower dam construction. *Aquatic Sciences* 77 (1): 161-170.
- <sup>7</sup> Baruch-Mordo, et al. 2019 (see note 5); Zarfl et al. 2015 (see note 6).
- <sup>8</sup> IRENA (2019). *Innovation landscape for a renewable-powered future*. International Renewable Energy Agency, Abu Dhabi.

### BOX 2

## KEY CONTRIBUTIONS TO A SUSTAINABLE ENERGY FUTURE

- Governments can (1) implement system-scale planning and licensing focused on integrated power systems to identify and develop those that are low cost, low carbon and low impact. Through this, countries can reassess plans for hydropower to factor in the full value of rivers and consider the availability of lower impact alternatives; and (2) create competitive frameworks to accelerate the renewable energy revolution to help them meet international commitments, most importantly national contributions to the Paris Agreement, SDGs, and CBD targets.
- Developers can facilitate the transition by supporting more comprehensive upstream planning and by improving their own project assessments using sustainability protocols and safeguards. Developers will benefit from a pipeline of lower-risk projects and, specifically for the hydropower sector, from providing higher-value ancillary services.
- Financial institutions can also support more comprehensive planning as a way to develop a pipeline of lower-risk projects, focusing their lending on opportunities emerging from such plans, and requiring their clients to apply ambitious sustainability protocols and safeguards. Making direct funding available for such activities can be critical. Financiers will benefit from lower-risk projects and, particularly relevant for development banks, accomplish diverse objectives, including multiple SDGs.



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