United Nations University
Institute for Water, Environment and Health

POLICYBRIEF

Doubling down on African hydropower might lock investments in inefficient and risky infrastructure

Executive Summary

1. Countries in continental Africa are considering more than 300 new hydropower projects to meet surging energy demand spurred by population growth and improved living standards.

2. Solar photovoltaics and wind power's plummeting costs are challenging the traditional dominance of hydropower in the African renewable capacity and generation mix.

3. Changes in water availability due to climate change are reducing the economic feasibility of hydropower projects in Africa.

4. Between 32% and 60% of the proposed hydropower capacity is not economically feasible in Africa.

5. Beyond 2030, the cost competitiveness of all new African hydropower will substantially decline.

Context

African nations are striving to meet increasing energy demands driven by population growth and improving living standards. Hydropower has long been regarded as an affordable source of fossil-free electricity and a substantial share of the remaining global techno-economic hydropower potential belongs to the African continent. However, solar photovoltaics and wind power are becoming increasingly competitive as a power generation source. Moreover, as climate change is going to affect water availability, hydropower generation might become less reliable.

Problem statement

The proliferation of hydropower projects, amidst shifting energy trends and climate change impacts, raises concerns about the cost-effectiveness of infrastructural investment. Hydropower projects, often associated with delays and cost overruns, can result in substantial impacts on the fluvial ecosystem and local communities. It is fundamental to assess which hydropower projects are most exposed to climate change impacts and competition with other sources in the techno-economic space to avoid directing investments towards risky and inefficient infrastructure. This policy brief recommends facilitating the development of cost-efficient climate-resilient hydropower projects while providing alternative solutions to prevent investment lock-in in the less techno-economic efficient ones to decision-makers involved in planning hydropower and power capacity expansion in Africa.

UNU INWEH

Policy Recommendations

Assess Hydropower Projects with Integrated Planning Frameworks
Decisions on the implementation of hydropower projects should be subject to a comprehensive economic viability analysis within integrated planning frameworks that consider climate change impacts, socio-economic projections, land-use change, demands and constraints associated with regional power and energy systems, and technological innovation. This planning practice can help prioritize climate-resilient and cost-effective energy sources, balancing short-term needs with long-term sustainability. Using a system perspective, investment in inefficient infrastructure can be avoided (Figure 1, Table 1, and Table 2).

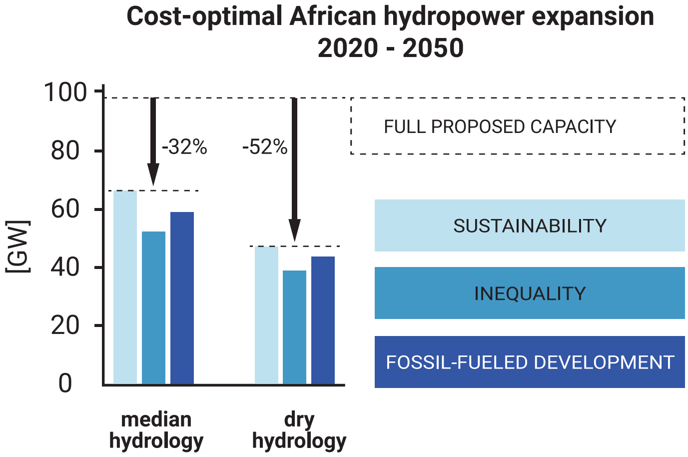

Figure 1. Cost-optimal African hydropower expansion. All projects under consideration reported in the African Hydropower Atlas were examined using an energy system planning perspective. Only between 40% and 68% of proposed hydropower capacity is cost-optimal. The uncertainty in our estimates depends on the different assumptions regarding future socio-economic projections, climate change scenario, and land-use (covered by the three scenarios 'Sustainability', 'Inequality', and 'Fossil-fueled development') and from the hydrological regimes considered (a median hydrological or a dry year).

Power Plant	Capacity [MW]
Inga 3 (DRC)	11050
Steigler's Gorge (Tanzania)	2100
Makurdi (Nigeria)	1010
Ayago (Uganda)	840
Onitsha (Nigeria)	750

Table 1. The largest African hydropower projects that are cost-optimal under all the scenarios examined.

Power Plant	Capacity [MW]
Inga 4 (DRC)	7424
Upper Mandaya (Ethiopia)	1700
Grand Eweng Ngodi (Cameroon)	1150
Beko Abo (Ethiopia)	935
Lower Grand (Kenya)	700

Table 2. The largest African hydropower projects that are never cost-optimal across all the scenarios examined.

Prioritize a Diversified Renewable Energy Investment
It is recommended to pursue investment strategies aiming at diversified renewable portfolios, emphasizing solar photovoltaics and wind power, which are becoming increasingly cost-effective and resilient against hydroclimatic variability. Accordingly, Africa's investment focus could be shifted from hydropower to solar and wind technologies to ensure economically viable capacity expansion. To this aim, at least 40% of the added capacity in this decade and more than 60% after 2030 could include a mix of solar photovoltaics and wind power (Figure 2). At the continental level, solar photovoltaics and wind are expected to generate more electricity than hydropower from 2040 and 2050, respectively (Figure 3).

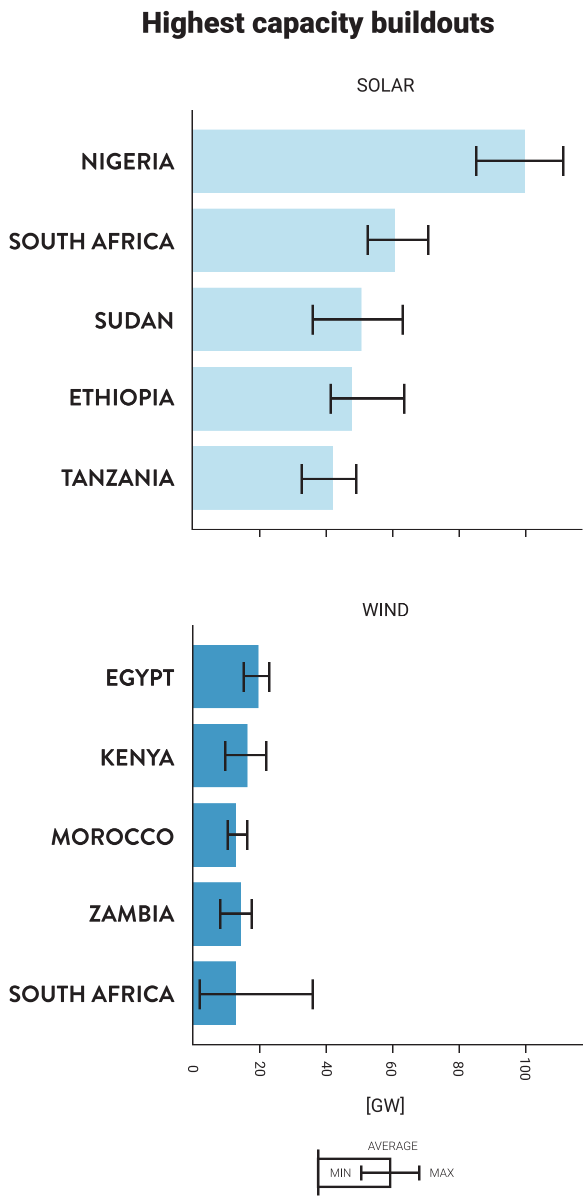

Figure 2. African countries with the highest solar and wind capacity buildouts over the period 2020-2050.

Contribution to the country-level generation mix

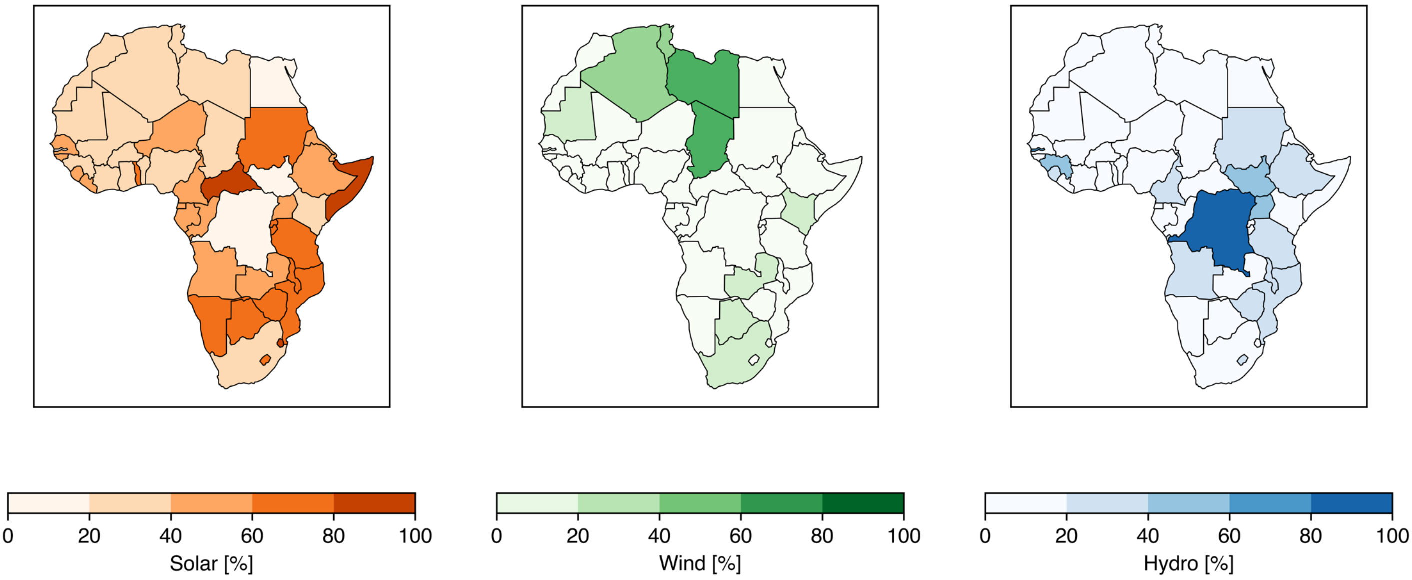

Figure 3. Country-level share of the generation mix in continental Africa in 2050 produced by solar, wind, and hydropower under the scenario with the highest climate policy ambition (SSP1-2.6).

Enable Cost-competitive Climate-resilient Hydropower Infrastructure
Hydropower development projects should be promoted only where technological competition and impacts of climate change are not undermining the economic viability of hydroelectricity. Generally, the proposed projects for the Congo River, the Nile River, and the Niger River Basins are consistently classified as cost-optimal under all the scenarios examined. The scenarios explore different climate change, socio-economic, land-use change, and hydrological futures while ensuring coherence between them. Even for these projects and especially for large hydropower dams, environmental and social impacts remain to be comprehensively assessed. The hydropower development projects that were not found cost-optimal under all scenarios should be further evaluated to understand the main drivers of their cost-ineffectiveness. For instance, projects located in the Zambezi River and smaller river basins represent a risky infrastructural investment that could be better directed towards solar photovoltaic or wind power.

Enhance Cross-Border Energy Cooperation
Fostering regional cooperation and power trading agreements will ensure energy security and stability in regions heavily reliant on hydropower (Table 4). Collaborative efforts can mitigate the impacts of hydroclimatic variability through shared resources and diversified energy sources. Designing an energy system less vulnerable to hydroclimatic impacts on hydropower comes with a 3% increase in annual investment costs. However, the distribution of costs and risks from hydropower is not homogeneous among countries. Incentive schemes will be needed to support investment in countries where costs will be borne to reduce risks in other regions.

Interconnections	Average power exchange [GW]
DRC - South Africa	1.3
Mozambique - South Africa	1.2
Tanzania - Kenya	1.0
Zambia - Zimbawe	0.9
Ethiopia - Kenya	0.7

Table 4. African countries with the largest average power exchange in 2050.

Final Remark

Strategic energy planning is essential to navigate the complex landscape of hydropower development in Africa. By adopting a systemic approach, African nations can avoid risky investments and secure a sustainable and resilient energy future.

Recommended Source

"More detail on the analysis of African hydropower projects is available in Carlino, A., Wildemeersch, M., Giuliani, M., Chawanda, C. J., Sterl, S., Thiery, W., van Griensven, A., Castelletti, A., (2023), “Declining cost of renewables and climate change curb the need for African hydropower expansion”, Science, 361, 6658,https://doi.org/10.1126/science.adf5848.

POLITECNICO MILANO 1863
International Institute for Applied Systems Analysis IIASA www.iiasa.ac.at
eci UNIVERSITY OF OXFORD
VUB VRIJE UNIVERSITEIT BRUSSEL

Authors

Dr. Angelo Carlino is a Postdoctoral Fellow at the Carnegie Institution for Science at Stanford University, working on decision-making support for climate and energy policy.

Dr. Matthias Wildemeersch is a Senior Research Associate at the Environmental Change Institute, University of Oxford. His current work focuses on energy systems, water governance, and food security.

Dr. Celray James Chawanda is a Postdoctoral Research Associate at Texas A&M AgriLife working on the impacts of climate change and land use cover change on water resources.

Dr. Matteo Giuliani is an Assistant Professor in the Environmental Intelligence Lab at Politecnico di Milano. The primary focus of his research is the integrated management of water resources in complex engineering systems.

Professor Sebastian Sterl is a Senior Researcher at the World Resource Institute (WRI) Africa and is a part-time Professor in Energy Meteorology at the Vrije Universiteit Brussel. He focuses on conducting model-based analyses of Africa's clean energy transition planning.

Professor Wim Thiery is a climate scientist focused on modelling extreme events in a changing climate. He is a Research Professor at the Vrije Universiteit Brussel, where he has established the BCLIMATE Group.

Professor Ann van Griensven is a professor in the Department of Hydrology and Hydraulic Engineering of the Vrije Universiteit Brussel and an Associate Professor of Hydrology and Water Quality at IHE-Delft. She is part of the developers team of the open source "Soil and Water Assessment Tool" as well as a board member of the SWAT foundation.

Professor Kaveh Madani is the Director of the United Nations University Institute for Water, Environment and Health (UNU-INWEH). He is an expert in the mathematical modeling of complex human-nature systems to advise policy.

Professor Andrea Castelletti is a Professor of Natural Resources Management and the founding head of the Environmental Intelligence Lab at Politecnico di Milano. He is an expert in water systems planning and control under uncertainty and risk, decision-making for complex engineering systems, and machine learning for environmental applications.

doi: 10.53328/INP23AAC01
ISBN: 978-92-808-6118-1

Recommended Citation: A. Carlino, M. Wildemeersch, C.J. Chawanda , M. Giuliani, S. Sterl , W. Thiery , A. van Griensven, K. Madani, A. Castelletti, (2023). Doubling down on African hydropower might lock investments in inefficient and risky infrastructure, United Nations University Institute for Water, Environment and Health (UNU-INWEH), doi:10.53328/INP23AAC01.