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Policy brief

Climate risks to hydropower supply in eastern and southern Africa

Headline issues

- Eastern and southern Africa are planning an extra 31 GW of hydropower capacity by 2030 to overcome electricity shortages.
- Most plants will be subject to similar rainfall patterns and thus will be exposed to similar potential climate-related disruptions.
- This could exacerbate other factors, such as governance challenges, that threaten reliable electricity supply and development.

Summary

The importance of hydropower electricity generation capacity is set to grow in many countries in eastern and southern Africa. There are 43 large-scale (more than 50 megawatt) hydropower projects planned up to 2030 in both regions, which would supply over 31 gigawatts of additional capacity. In many countries hydropower is a significant source of electricity generation and will continue to be so.

Approximately 82% of the new hydropower capacity in eastern Africa is planned for the Nile basin, and 89% of southern Africa's for the Zambezi basin. Within each basin these plants would be vulnerable to the same climatic variations as their locations and river basins share similar patterns of rainfall. Projected changes in the seasonal distribution and amount of rainfall due to climate change could result in even larger variations.

This exposure could lead to impacts on the generation performance of multiple plants at the same time, with concurrent and potentially significant knock-on effects through domestic and regional power systems, and could adversely affect socioeconomic development.

Policy briefs provide analysis on topical issues, presenting specific recommendations to inform ongoing policy debates. Drawing on the Grantham Research Institute's expertise, they summarise either our research findings or the state of knowledge about a particular issue.

This policy brief has been written by **Declan Conway, Patrick Curran** and **Kate Elizabeth Gannon.**

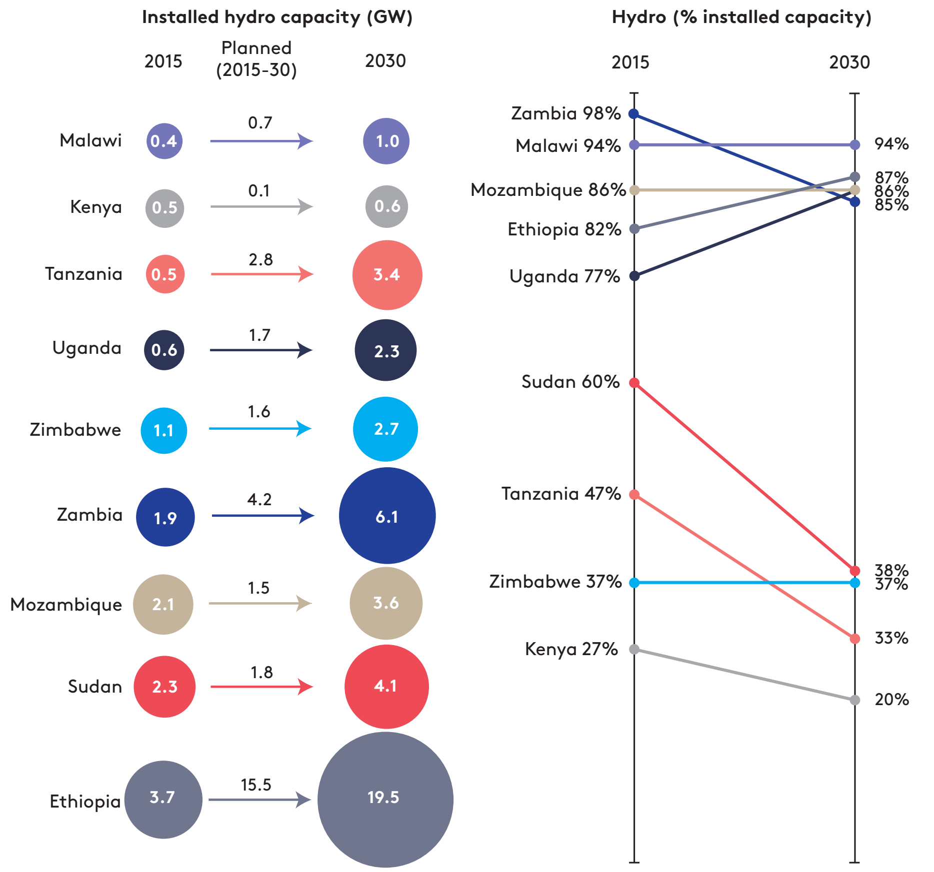
“Recent disruptions to electricity supply highlight the challenges of chronic electricity scarcity and impede the achievement of development targets”

Introduction: increasing electricity demand and risk to supply in eastern and southern Africa

Disruption to electricity supply has been experienced recently in a number of countries in eastern and southern Africa, including Kenya, Malawi, Mozambique, Zambia and Zimbabwe. These disruptions highlight the challenges of chronic electricity scarcity and impede the achievement of development targets, particularly the two Sustainable Development Goals (SDGs) that target provision of sustainable, reliable, accessible and affordable electricity (SDGs 7 and 13). To fulfil socioeconomic objectives, it is estimated by the Programme for Infrastructure Development in Africa (PIDA) that electricity-generating capacity needs to increase by 6% per year to 2040 (African Development Bank, 2016).

Many countries in the two regions have a preference for hydropower. There are currently 43 large-scale (more than 50 megawatt [MW]) projects planned up to 2030 (Conway et al., 2017). This will add over 31 gigawatts (GW) of additional hydropower capacity, taking the total to 58 GW. However, in light of unpredictable climate change and potentially heightened rainfall variability, increasing reliance on hydropower could pose significant risks to

Figure 1. Hydropower in the eight countries of eastern and southern Africa with the most planned capacity (overall installed and planned capacity and contribution to overall generation capacity)



Note: South Africa has been excluded due to a lack of planned large-scale hydropower projects to 2030

Source: Compiled by authors using data from Conway et al. (2017), USAID (2017), Government of Uganda (2015), Ministry of Energy and Minerals (2015), Singh (2013) security of supply, the impacts of which are already being experienced.

Current and future importance of hydropower in the regions

With the exception of South Africa, current installed electricity generation capacity is low relative to current and anticipated demand, an average of 1 GW per country (Energy Information Administration, 2018).

Of current installed capacity, hydropower constitutes a large proportion, accounting for over 20% in 17 countries in the regions and above 50% in many of them (ibid.). Hydropower capacity is also set to increase in the future to 2030 (see Figure 1). If all the planned plants are built, hydropower capacity in eastern Africa will grow by a factor of two, with 82% (28.78 GW) located in the Nile basin. In southern Africa, hydropower capacity would also double, to 13 GW, nearly all of which would be in the Zambezi basin (see Figure 2).

At a country level, Ethiopia is planning the most new capacity, aiming to triple its current installed capacity, mostly in the Nile basin, to comprise 87% of total generation capacity in 2030. This level of contribution, albeit with lower absolute capacities, is also evident in the energy plans of Malawi, Mozambique, Uganda and Zambia.

Increasing risk of concurrent climate-related disruption to hydropower and electricity generation

Given the long lifespan (greater than 50 years) of hydropower infrastructure and its reliance on water availability and climatic conditions for operation, any large fluctuations in either over time could pose significant risks to performance and therefore electricity supply at times. Rainfall variability, in the form of dry and wet periods, is an important feature of much of sub-Saharan Africa's climate and in the Nile and Zambezi basins is responsible for significant fluctuations in lake levels and river flows.

Conway et al. (2017) analysed the spatial distribution of rainfall in the regions in order to understand the exposure of these hydropower resources to climatic fluctuations. Using historical rainfall data and cluster analysis to group areas with similar rainfall variability, three areas of shared rainfall variability were found in eastern Africa and seven in southern Africa, as shown in Figure 2 (p4). Within each region the majority of the hydropower plants are currently reliant on areas of the same rainfall variability and will continue to be so.

If all plants are built by 2030, 70% of generating capacity in eastern Africa and 59% in southern Africa will be dependent on areas with similar rainfall patterns (ibid.). These plants are therefore likely to experience wet and dry years at the same time. This exposure could lead to simultaneous impacts on the generation performance of multiple individual plants, with potentially major concurrent knock-on effects through domestic and regional power systems.

Changes in future water flows due to climate change could also have an impact on the future availability of rainfall and surface water; projected changes would

> "If all the planned plants are built, hydropower in both eastern and southern Africa would double by 2030"

> "The spatial distribution of hydropower capacity is important as some of the countries and regions are interconnected via electricity trading pools"

result in marginal increases to decreases of 10% to 20%. This could have a significant impact on generation performance.

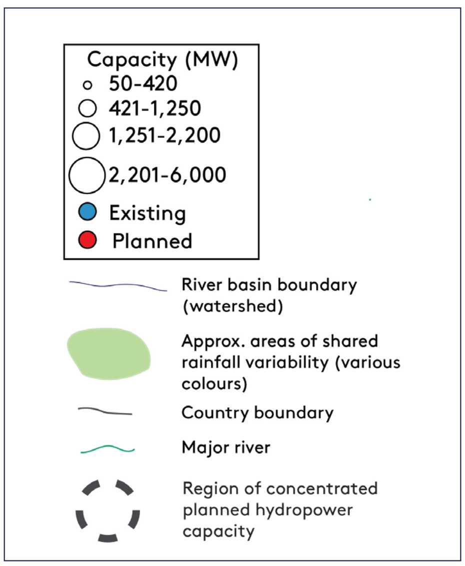
Climate models project warmer and slightly wetter conditions in eastern Africa, and warmer and slightly drier conditions in southern Africa (IPCC, 2013). While there are differences between climate model results for future rainfall, the variability and frequency of extremes are expected to increase.

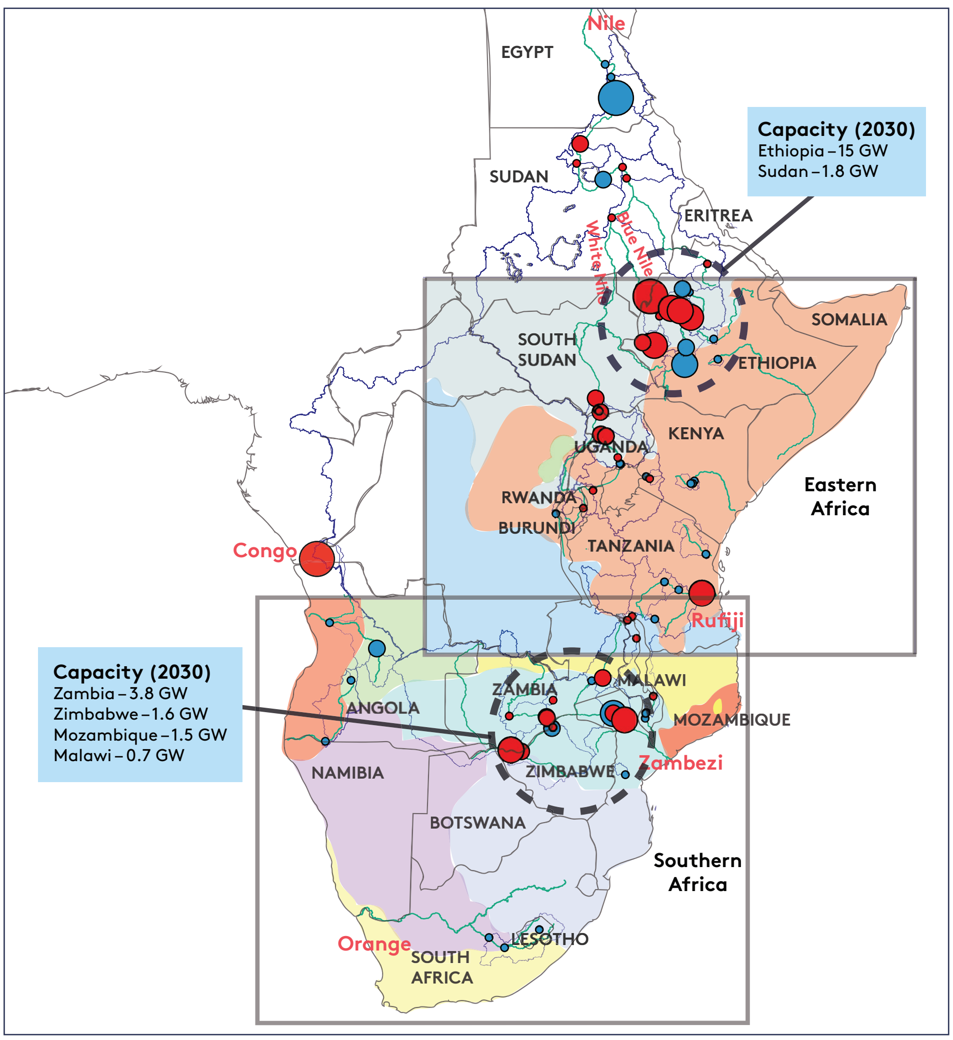
The current ability of most climate models to simulate the large-scale climate processes in Africa is limited. This is not to suggest that climate change projections should be excluded from future planning but rather that more effort should be made to utilise actual observations. This would aid in understanding changes to clusters and managing the risk of future large-scale climate disruption.

Climate change and hydropower disruption across countries

The spatial distribution of hydropower capacity is important as some of the countries and regions under discussion are interconnected via electricity trading pools: the Southern African Power Pool (SAPP) and the East African Power Pool

Figure 2. Rainfall zones and existing and planned hydropower capacity in eastern and southern Africa





Source: Authors, adapted from Conway et al. (2017)

(EAPP). Although at different stages of operation, both of these power pools are intended to allow electricity to be traded between countries to help meet domestic demand, or to sell excess capacity.

Unpredictable changes in water availability clearly pose significant risks to the future viability of individual hydropower plants and electricity security of individual countries, but when these are aggregated across a region, the risk is greater still. Concurrent individual disruption could potentially threaten the electricity security of multiple countries at the same time, including those, such as South Africa, that do not have large installed hydropower capacity but draw on other pool members that do.

As discussed above, countries including Ethiopia, Sudan and Uganda will be reliant on generation capacity located in the Nile basin and the same rainfall zone. They are also all members of the same power pool, and thus all are exposed to the risks of concurrent climate-related electricity supply disruptions.

Similarly, in southern Africa, countries including Malawi, Mozambique, Zambia and Zimbabwe could be exposed to concurrent climate-related electricity supply disruptions, because rainfall variability in the Zambezi basin and shared rainfall zone will affect multiple dam sites supplying the same power pool.

However, the relationship between climate-related events between the major basins (Nile and Zambezi) is generally weak (Conway et al., 2017). When one basin is experiencing periods of low rainfall, another may not be. For example, there is a weak relationship between both the two key rivers in eastern Africa (Blue Nile and Lake Victoria outflows) and between these rivers and the key river in southern Africa (the Zambezi). The correlation is also small between all three and the Congo, Africa's largest river, which has substantial untapped hydropower potential.

The climate-related risks to a country or region's electricity supply could therefore potentially be mitigated, at least in part, via the current and planned electricity power pools, which could allow electricity to be traded between countries with available capacity, to compensate for those where supply is curtailed due to climatic conditions. However, this would also need to support electricity trading across regions (SAPP or EAPP), not just within the same region.

Climate change and hydropower as an electricity security risk multiplier

Risks to electricity supply in sub-Saharan Africa are not only concentrated in the generation side: they extend through the electricity sector. While disruption to generation caused by climatic factors would have a knock-on effect through the sector, these factors could also serve to exacerbate existing non-climatic challenges in these countries. These include under-investment in electricity infrastructure, policy uncertainty, governance challenges, poor local service provision, and in places a combination of all of these.

"Disruption to generation caused by climatic factors could also serve to exacerbate existing non-climatic challenges related to electricity generation, supply and security"

"Climate-related challenges to hydropower operation could act as risk multipliers as they expose and exacerbate other weaknesses"

Within the Nile and the Zambezi river basins, the countries that are, or plan to be, the most reliant on hydropower are also those that are most vulnerable to climate-related supply disruptions and have relatively weak governance systems (World Bank, 2017).

Climate-related impacts could be the initial cause of a reduction in electricity supply, but a weak management response or failure to plan (or learn) can exacerbate the impact of the disruption, or create barriers to a timely recovery.

While shocks could also serve to spur action, it is important to recognise the complexity of their causes in order to implement the best set of solutions to mitigate against such shocks in the future. The shocks commonly represent an episodic problem set against enduring critical governance-related challenges in many countries.

Zambia provides an example of the complex socioeconomic linkages between climate-related disruptions, hydropower, electricity security, weaker governance and development (see Box 1).

Box 1. Climate-related electricity supply disruption and socioeconomic development in Zambia

Historically, Zambia has had an energy surplus, with hydropower being the dominant form of electricity generation, but increasing numbers of people connecting to the grid as the country develops have caused a surge in demand.

Supply was adversely affected by the El Niño climate event of 2015 and 2016 (one of the strongest since 1950), which contributed to the Upper Zambezi catchment experiencing moderate to extremely dry conditions for a prolonged period.

This dry period caused markedly reduced inflows into Lake Kariba, on which Zambia's hydropower supply is reliant, until March 2016 (Siderius et al., 2018). Water levels dropped as low as 12% of capacity in January 2016, just above the minimum operating level for electricity generation.

This contributed to a 7% decline in capacity and a major national power deficit: to manage the unanticipated shortfalls the energy utility ZESCO pursued a policy of planned daily power outages (load-shedding), unprecedented in scale. The resultant multi-hour-long blackouts particularly affected Lusaka Province and the Copper Belt, where most electricity is consumed.

Water and hydropower management decisions further exacerbated this situation. Hydropower capacity on Lake Kariba has increased in recent years, but reservoir storage has not. The newly installed capacity requires higher outflows from Lake Kariba. Combined, the high outflows and low rainfall contributed to low lake levels, in turn reducing hydropower output.

The load-shedding and enforced demand reduction caused industrial sectors including mining to experience widespread shutdowns, job losses and reduced production. Further, micro, small and medium enterprises (MSMEs) in Lusaka – major employers – reported electricity supply disruption to be their leading business challenge (Gannon et al., forthcoming): manufacturing, and services have to be suspended during load-shedding and further damage is caused by a lack of heating and refrigeration. These factors, combined with a fall in global copper prices and low agricultural output due to the drought, caused real economic growth in 2015 to drop to its lowest rate in more than 15 years, with estimated national losses of around 19% of GDP (Samboko et al., 2016).

The results described in this box are from a collaboration between the Grantham Research Institute and: University of Barotseland, Zambia (M. Ndiyoi and M. Nyambe); Botswana Institute for Technology Research and Innovation, Gaborone, Botswana (N. Batisani and S. Kgosietsile); and African Collaborative Centre for Earth System Science, University of Nairobi, Kenya (E. Odada, D. Olago, A. Opere and J. Omukuti).

Policy recommendations

1. Greater recognition of the increasing risk of climate-induced electricity supply disruption is required.

- **Regional and country-specific energy sector planners and system operators** should explicitly recognise the spatial linkages and climate risks related to hydropower. This should be integrated into system-wide domestic and regional energy planning processes that recognise the complementarity of other renewable energy sources.
- **National policymakers** should commission independent studies of the causal linkages between concentrating hydropower plants in the same basins, plus projections of climate-related variability and the impacts on domestic electricity security.
- **Development finance institutions** should ensure that the risks of climate-related generation disruption, in particular rainfall variability and water flows and the clustering of hydropower projects, are factored into investment decisions.

2. Investment in regional electricity connections should take into account potential climate-related linkages and be designed to minimise the climate-related risks to electricity supply.

- **National governments and development finance institutions** should prioritise increased investment in cross-country transmission lines that link across rainfall clusters with low correlations to support the diversification of risks posed by climate-related hydropower disruption.
- **The EAPP and SAPP** should undertake regular (five-yearly) detailed studies of rainfall clusters for both the present and future climate scenarios. These should be incorporated into risk and stability assessments of interconnected regional electricity systems.
- **The relevant regional institutions,** the Southern African Development Community and the East African Community, should facilitate knowledge-sharing and engagement between countries to understand exposure of regional electricity systems to climate-related supply disruptions and develop transboundary plans to manage these risks.

3. Climate change-related rainfall disruptions must be addressed in conjunction with additional planning for climate resilience.

- **Development agencies** that support capacity-building and strengthening of governance should prioritise adaptive management that incorporates review and adjustment of responses, with increased emphasis on planning and contingency.
- **Development agencies and development finance institutions** should support the development of guidelines to incorporate domestic and regional climate risks into infrastructure planning. Guidelines need to be practical

> "Climate change-related rainfall disruptions must be addressed in conjunction with additional planning for climate resilience"

and adopted as key stages in the planning and design of infrastructure investment.

- **National policymakers and regional electricity managers** should support the communication of risks to supply in advance, including publishing and keeping to load-shedding schedules. Development agencies should support MSMEs and other businesses to adequately plan and adapt and to reduce damage to property and assets.

Conclusions

Many hydropower plants will be located in river basins that are exposed to similar climate-related disruptions that not only pose a risk to generation capacity but are also set against structural challenges presented by weak governance. Without management responses or strengthening of governance systems that can adequately manage climate impacts, existing weaknesses could deepen. This could risk aspirations to maximise many of the economic and social development opportunities presented by reliable and predictable electricity supply.

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