Climate Compatible Growth

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Enabling Southern Africa's Transition to a Low-Carbon Electricity System

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Summary

Southern Africa faces the dual challenge of providing affordable energy to meet its rapidly growing electricity demand while limiting carbon emissions and socio-environmental impacts. We developed cost-optimal low-carbon electricity pathways for the 12 mainland countries of Southern Africa. In contrast to existing regional plans, our results show a dominant role for wind, solar PV, and battery storage technologies. Importantly, we found no new coal generation capacity and only about half of planned hydropower capacity to be cost-effective. High clean energy targets (80% of total generation) and greater consideration for biodiversity protection and socio-economic impacts incur modest costs (6% and 2% increase respectively). We provide policy recommendations to enable this sustainable, low-carbon electricity transition in Southern Africa.

Key Policy Recommendations

- Increasing annual wind and solar energy procurement by up to 5 times the current rate by 2040 is the least-cost strategy to meet growing future electricity demand in Southern Africa.
- No new coal power plants were found to be cost-effective and hence should be avoided
- Planned hydropower projects should be critically re-evaluated as half of the planned capacity was found to be not cost-effective.
- Competitive electricity trade through the Southern African wholesale electricity market should be increased by at least 5 times and inter-regional transmission capacity should be at least doubled for sharing both renewable and conventional energy resources across the region.
- Development of hydropower, wind, and solar PV projects in areas with high biodiversity should be avoided, a strategy that would incur less than 5% additional costs.
- The additional costs of adopting clean energy targets or retiring coal plants 20 years early to halve GHG emissions by 2040 should be offset through low-cost international financing and climate grants.

IMAGE: ANASTASIA PALAGUTINA/UNSPLASH

Introduction

Electricity demand in the 12 countries of the Southern African Power Pool (SAPP) – Angola, Botswana, Democratic Republic of the Congo, Eswatini, Lesotho, Mozambique, Malawi, Namibia, South Africa, Tanzania, Zambia, and Zimbabwe **(Figure 1)** – is projected to double by 2040 [1]. Collectively, these countries represent about 40% of total electricity demand and about 40% of total carbon emissions in Africa. The challenge is to meet this growing demand while limiting greenhouse gas (GHG) emissions, protecting the unique biodiversity of the region, and limiting negative socio-economic impacts. However, Southern Africa's electricity system is dominated by coal and large hydropower (60% and 21% of total installed capacity in 2020, respectively) [1]. More importantly, current regional electricity plans emphasize development of new coal, hydropower, and natural gas to meet rising demand. This is despite vast wind and solar resources and the rapidly declining costs of wind and solar technologies [1].

Figure 1. Southern African Power Pool and mainland member countries (Malawi, Eswatini, and Lesotho not labelled).

Our team from the University of California Santa Barbara, the Southern African Development Community (SADC) Centre for Renewable Energy and Energy Efficiency, The Nature Conservancy, and the University of Cape Town asked the following research questions:

1) **What are the cost optimal investments in generation, storage, and inter-regional transmission in Southern Africa under different techno-economic, structural, and climate policy scenarios?**
2) **What are the costs, if any, needed to achieve greater environmental protection and social considerations in wind, solar, and hydropower siting?**

> *"If decisions are based on cost alone, wind and solar PV technologies could be the dominant source of electricity in the region by 2040"*

The analysis aimed to incorporate the declining costs of renewable energy and storage technologies as well as improved the representation of the variability of wind and solar generation, the seasonality of hydropower generation, and inter-regional electricity trade. This was done by developing a detailed electricity system optimization model for Southern Africa to select the most cost-optimal generation, storage, and inter-regional transmission investments that would meet the region's future electricity demand until 2040 [2]. The electricity system cost optimization model [3] and data [4] are free and opensource for policymakers, planners, and other stakeholders to use in electricity planning processes.

The scenarios had the following characteristics:

- varying combinations of capital costs for solar, wind, and battery storage (National Renewable Energy Laboratory's forecasts),
- price forecasts for fossil fuels [1]
- inter-regional transmission interconnections
- retirement ages of installed coal fleets

One scenario specifically modelled a clean electricity target of 80% by 2040, which roughly halves annual GHG emissions. For details of all scenarios see **Figure 2**.

Further, using fine resolution (500 metres) spatial data on wind and solar resources, and project-specific hydropower flows and operations, we excluded potential sites based on different environmental and social criteria. For example, in a less environmentally protective scenario, only sites that overlapped with legally protected areas (national parks) were excluded, whereas in the more environmentally protective scenario, sites in unprotected forested areas were also excluded from development. The electricity system model then chose the most cost-optimal sites from these different scenarios of candidate wind, solar, and hydropower sites, which allowed us to estimate the additional costs imposed by greater environmental protection and social considerations in energy siting [5].

> *No new coal capacity is economical in any of the 12 countries of the Southern African Power Pool*

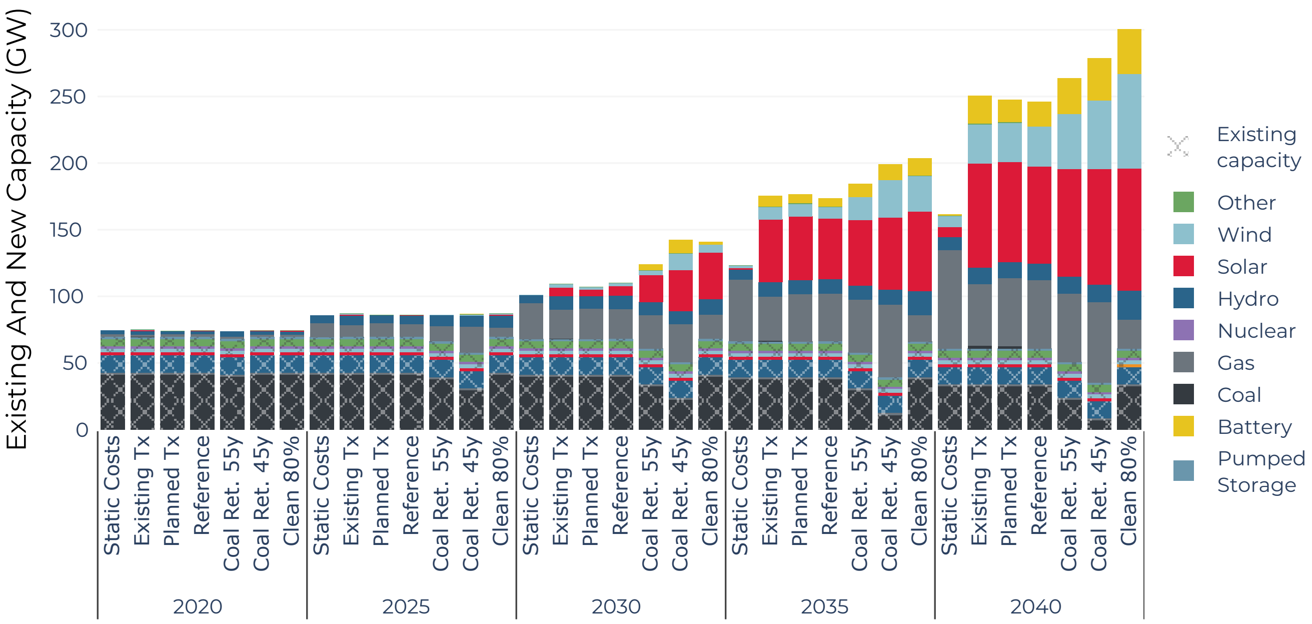

Figure 2. Existing and new generation capacity in Southern Africa across 2020–2040 for seven scenarios [2]. Scenarios (not in order) are: (1) ***reference*** *scenario with optimally built inter-regional transmission and coal power plant retirements at 65 years; (2) only* ***existing transmission*** *(Tx) capacity; (3) only* ***planned transmission*** *capacity; (4)* ***static technology and fuel costs*** *(same as 2020); (5 & 6)* ***coal power plants retired earlier at 55 years and 45 years lifetimes****; and (7) a* ***clean energy target of 80%*** *of energy generation across the SAPP.*

Key Results

1) If technology and fossil fuel costs follow anticipated trends, wind and solar PV technologies are likely to cost-competitively dominate future electricity generation investments in Southern Africa. If decisions are based on cost alone, these technologies could be the dominant source of electricity in the region by 2040 (Figure 2) [2].
2) No new coal capacity is economical in any of the twelve countries of SAPP, except when inter-regional transmission capacity is constrained (Figure 2) [2].
3) Despite the abundance of planned hydropower (43 GW based on the SAPP Master Plan [1]), almost half of all planned hydropower capacity is uneconomic across all scenarios.
4) Increased inter-regional transmission capacity (2–10 times more depending on the corridor) and significantly greater electricity trade (5 times more) compared to the present is critical for future cost-optimal and low-carbon power system operations in Southern Africa [2].
5) Considering environmental and social siting criteria results in minor cost increases (less than 2% by 2040 with all environmental and social exclusions for wind, solar, and hydropower; and less than 5% with no planned hydropower projects) [5].
6) By 2040, Southern African can cut its annual GHG emissions to half of 2020 emissions by adopting an 80% clean energy target, which will cost only a modest 6% increase annually or USD 9 billion over a 20 year period (2020–2040) compared to the reference scenario. Alternatively, retiring coal power plants at 45 years of age (20 years earlier than our reference scenario) could result in even greater emission reductions but will incur 12% higher annual costs or USD 20 billion over 20 years **(Figure 3)**.

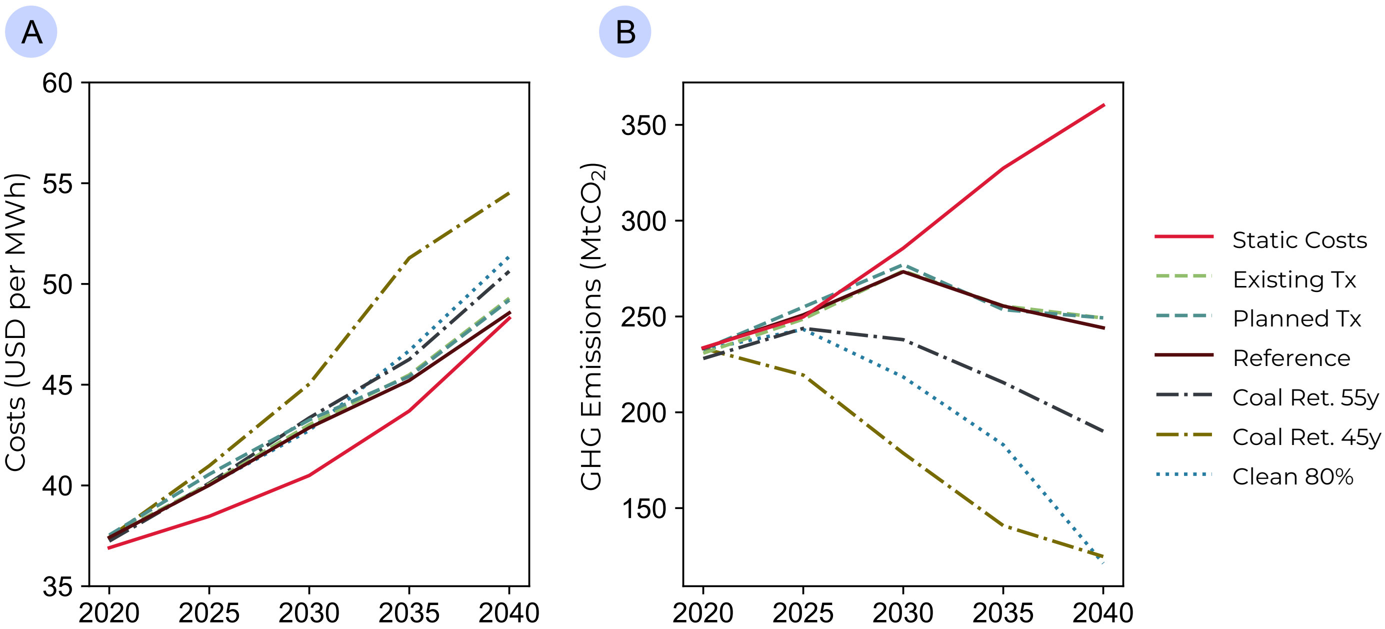

Figure 3. Annual system costs (operating and investment) and GHG emissions across 2020–2040 for seven scenarios [2]. See Figure 2 for scenario descriptions. Capital costs of existing generation infrastructure are assumed to be the same and sunk across all scenarios. They are excluded from total systems costs. Costs depicted here all increase over time because fixed costs of existing infrastructure comprise a greater share of total costs in earlier years. This does not imply that average annual costs increase over time.

Policy Recommendations

The Southern African region has tangible opportunities for limiting future electricity sector emissions at a relatively low cost premium. The key enabling factors are the declining costs of wind, solar PV, and battery storage technologies. Importantly, all energy pathways minimally rely on hydropower. All except one avoid new coal, thereby limiting GHG emissions, improving health impacts, and helping to protect ecosystems of key global importance. Based on our findings, the following are policy recommendations for enabling Southern Africa's low-carbon energy transition.

1) The Southern Africa region should **increase wind and solar energy procurement rates by 5 fold**, the least-cost strategy for meeting future electricity demand.
2) **New coal power plants should be avoided** because they are not cost-effective for Southern Africa.
3) Southern Africa should **critically re-evaluate its plans for hydropower projects** as about half of planned hydropower capacity is unlikely to be cost-effective.
4) **Competitive electricity trade** through the Southern African wholesale electricity market should be increased by at least 5 times and **inter-regional transmission capacity should be at least doubled** for sharing both renewable and conventional energy resources across the region.
5) Governments of Southern African countries should **avoid development of hydropower, wind, and solar PV projects in areas with high biodiversity**. Such a strategy will incur minor costs to electricity consumers while avoiding the delays, hurdles, and costs that come with siting conflicts.
6) Additional costs of adopting clean energy targets or retiring coal plants 20 years early (5–15% of generation costs) in Southern Africa to halve GHG emissions by 2040 should be supported through low-cost international financing and climate grants. **International climate funding could provide the additional direct costs** of such targets and also finance the employment opportunities needed to ensure an equitable transition. An example is the COP26 pledge of USD 8.5 billion fund by the US, UK, and EU to support the phase-out of coal in South Africa, the country with the most coal capacity and highest GHG emissions in Africa.

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