NOTE 4

Embedding Climate Resilience into Energy Projects

The Africa Climate Resilience Investment Facility (AFRI-RES) Learning Note

1. Why is resilience important for energy projects?

While electricity is required for almost all modern economic activity, in Sub-Saharan Africa access to power is limited: over 640 million are not connected to power supplies (African Development Bank 2019). Continuation of a business as usual pace, alongside population increase, will see 530 million people still without electricity in 2030 (90 percent of global number). The overall goal in Africa is therefore to increase energy access as a critical enabler of resilience, which will generate economy wide benefits and harness the abundant renewable endowments in the face of falling prices of renewable energy (World Bank 2020). Additionally, in places where there is access to electricity, supply is often poor and failures can be exacerbated by changes in climate. For example, unusual recent extended droughts in the Zambezi River basin have resulted in prolonged periods of power shortages from its hydropower plants, which causes heavy economic losses (World Bank 2023b).

Resilience is thus important in all networked infrastructure projects, and electricity services specifically — and particularly those that

The Africa Climate Resilience Investment Facility (AFRI-RES) is a partnership between the Africa Union, African Development Bank, the United Nations Economic Commission for Africa (UNECA), and the World Bank Group, established with support from the Nordic Development Fund (NDF). The partnership seeks to assist governments, planners, and private developers in integrating climate resilience in project planning and design, thereby attracting funding from both development and climate finance sources.

This note summarizes lessons and practices deployed in embedding climate resilience into the design of projects that received catalytic funds from AFRI-RES. It draws from application of the Resilience Booster Tool to specific projects, as relevant, Compendium Volume on Climate Resilient Investment in Sub-Saharan Africa (World Bank (2023a) and Guidance, Standards, and Good Practice Notes developed under the program.

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deliver critical services in the context of a power system. Resilient service delivery means that end users (businesses, homes, community infrastructure) see minimal disruptions to electricity services even if certain aspects of the system suffer damages or failures. Resilient energy projects are designed to continue delivering services even in the face of climate hazards such as floods, landslides, cyclones, and storms, and other stressors. If not accounted for in project design and operation, the impacts of such events may result in the loss of electricity and revenue and costly repairs. Ultimately, integrating resilience early in project design and implementation protects investments and delivers lasting benefits.

The threat to infrastructure assets from natural hazards and climate change, which will increase the frequency and magnitude of natural hazards, is widely recognized.[1] The direct costs from reduced power use and lost sales—not to mention lost lives and livelihoods—are estimated at US$120 billion annually in low- and middle-income countries. In many parts of Africa, losses from reduced use of disrupted infrastructure exceed 0.8 percent, higher than most other regions globally. The climate hazards that can affect the energy sector include changes in air temperature, precipitation, radiation, wind speed, humidity, and in turn runoff, cloudiness, wind density, biomass yield, water temperature, and air temperature. These may occur over short high intensity events. A hailstorm may destroy solar panels for example. At the same time, they may occur over prolonged periods, such as the gradual increase of temperature over decades. Once parts of a system are damaged, especially transmission and distribution assets, coordination across other infrastructure sectors, such as telecommunication and transportation, is required to access and repair the damaged assets.

Furthermore, energy systems and their constituent supply chains can be impacted not only by their physical construction but also by how the system

1 This section was converted from Shweikert, Ramstein, and Nicolas (2022), which draws on the following works: Albert, Albert, and Nakarado (2004); Cervigni et al. (2015); CIMA Research Foundation (2019); Comes and de Walle (2014); Fekete, Hufschmidt, and Kruse (2014); Hallegatte, Rentschler, and Rozenberg (2019); Karagiannis et al. (2017); Loggins et al. (2019); Murphy et al. (2020); New York Power Authority et al. (2017); Nicolas et al. (2019); Oguah and Khosla (2017); Panteli and Mancarella (2015); Schweikert and Deinert (2021); and Sebastian et al. (2017).

is operated and managed. Typically, integrated power system chains are designed to include 'reserve margins', which help increase their ability to withstand hazards. However, these margins, as well as their design and operation, can struggle under current climatic change and geopolitical conditions.

Fortunately, opportunities abound to incorporate resilience in new infrastructure projects. In most cases, engineering and systems-level solutions can reduce the vulnerability of power assets to stressors and increase the overall reliability of service. For example, system assets can be built to withstand hazard conditions, known as hardening. A system can be designed for redundancy to, for example, quickly reroute power or include backup options such as batteries, diesel generators, or other technologies. When damages exceed operational levels, repairs can be accelerated if disaster management protocols include repairs and recovery plans such as stockpiling of parts, access to trained personnel, and secure access to sites. All of these measures increase the resilience of critical power assets and systems.

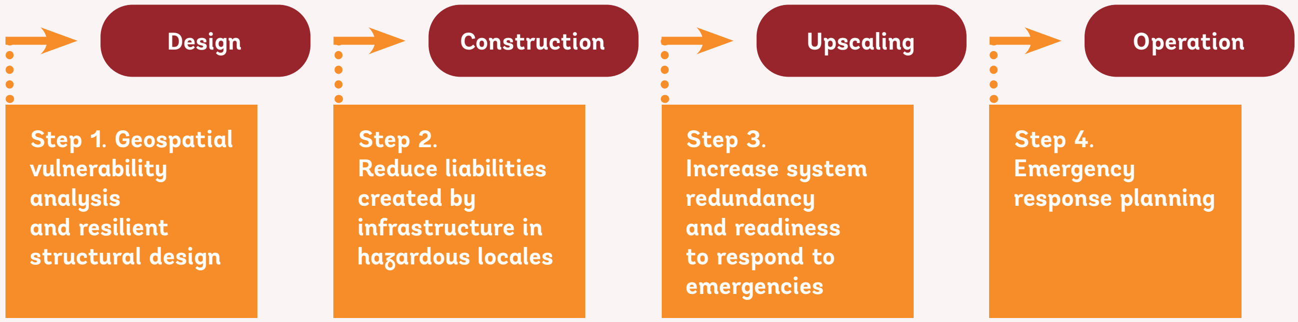
The World Bank created and deployed the Resilience Rating System[2] because proactive resilience planning and investments can have positive impacts across project lifetimes for both financial return and service delivery. The first part of resilience rating relates to the project: how it performs under stress from discrete events like a cyclone or flood, as well as ongoing stresses from climate change. The second part is the resilience created by a project to the sector or beneficiaries. In the energy sector, strengthening a project's resilience might include asset hardening, siting considerations, emergency planning, supply chain considerations, and more. Projects that add resilience include ones that increase electricity access and reliability, build capacity, or improve maintenance and emergency procedures.

2. How do you build resilience into an energy-system project?

For energy infrastructure, resilient investments can be classified into four categories, those that (a) reduce asset vulnerability; (b) reduce liabilities and hazardous conditions created by infrastructure; (c) enhance the reliability and service delivery of the electricity network; or (d) reduce the response time and increase the capacity to respond when natural hazards occur. Each investment type can occur at various times in the planning, construction, and operation of an energy system (Figure 1). Asset hardening, operations and maintenance (O&M), and efficient disaster response and recovery plans can increase resilience. After identifying the greatest threats and gathering information on the local context, including institutional capacity and resources, one can proceed with investment planning.

2 The Resilience Rating System methodology is detailed in World Bank Group (2021). Many of the projects are part of pilots applying these concepts.

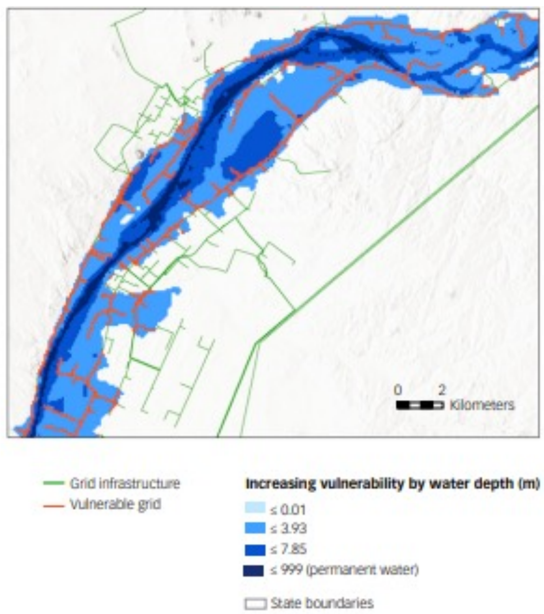
Figure 1. Framework for enhancing the resilience of energy sector projects at different phases of implementation



Step 1. Reducing asset vulnerability.

Assets can be made less vulnerable by siting them outside the highest-risk regions and by hardening infrastructure. For example, project design can include specifications that ensure it can sustain natural hazards of greater intensity than historical conditions may indicate. Geospatial analysis can identify high-risk regions (see figure 2. Systematic assessment of proposed infrastructure locations can help identify the expected historical stressors and projected climate change impacts. This is crucial with climate change because many design standards are based on historical conditions that may not encompass the range of extreme events expected. In many locations, climate change is expected to exacerbate the frequency or severity of flooding, for example, and may increase the expected damages to infrastructure. Several adaptation and mitigation strategies may be employed. If possible, not siting assets in high-risk regions may be the most cost-effective approach. If this is not possible, adaptation options might include elevating photovoltaic (PV) panels and other infrastructure assets, building flood walls, or waterproofing key components (see figure 2). Planners should assess the direction and speed of strong wind events, especially for rooftop-mounted PV systems. Inevitably, some assets cannot fully avoid high-risk locations. Therefore, identifying expected stress from natural hazards and climate change can inform design decisions.

Figure 2. Sample Hazard Assessment Highlighting Grid Assets Vulnerable to Flooding



Source: Shweikert et al, 2022.

Step 2. Reduce liabilities and hazardous conditions created by infrastructure.

Reducing the liability or risks that infrastructure poses to the environment and communities it serves is part of resilient siting, design, and operations. Transmission and distribution systems can pose a risk of wildfires, especially during hot, dry periods. It typically involves the arcing, or contact, of transmission or distribution wires with very dry vegetation. For example, the US Pacific Gas and Electric Company filed for bankruptcy in January 2019 owing to an estimated liability of US$30 billion from wildfires caused by power lines it owned and operated. The fires killed over 100 people, burned thousands of acres, and required compensation of billions of dollars. Designing lines with aerial bundled cable and conductors in high-risk regions could reduce the likelihood of such risks but requires an additional investment of up to 60 percent of construction costs. Less expensive options include vigilant vegetation management and turning the lines off at times of extreme risk, such as during periods of high winds and drought.

Figure 3. Adaptation Measures to Protect Infrastructure Assets from Flooding

a. https://en.wikipedia.org/wiki/Photovoltaic_mounting_system. Licensed for free use under by CC 2.0
b. https://side.developpement-durable.gouv.fr/NORM/doc/SYRACUSE/6934/reduire-la-vulnerabilite-des-reseaux-urbains-aux-inondations.
c and d. https://www.blackshieldshvac.com/applications/climate-control-solutions-for-bess/

Source: Shweikert et al, 2022.
Note: PV = photovoltaic.

Step 3. Enhance the reliability and service delivery of the electricity network.

Routine maintenance, emergency backup generation options, and redundant systems can enhance the reliability of service delivery. Regular maintenance for PV panels includes inspection for damages and dirt to ensure the arrays are delivering their full generation potential. This requires access to the infrastructure and raises the question of panel placement (for example, rooftops can be difficult to access). Elevated temperatures can increase the rate of battery degradation. Therefore, for battery storage, ensuring that ventilation systems are clean, free of debris, and adequate for cooling during times of high demand supports proper system operation and minimizes damages. Completely avoiding all damages from climate change and natural hazards is not possible—and trying to achieve it would be extremely costly. Increasing resilience is instead about finding the right balance of redundancy, hardening, and readiness to respond and rebuild rapidly when a disaster hits.

Step 4. Reduce the response time and increase the capacity to respond when natural hazards occur.

The final component of a resilient power system is an emergency response plan. This should consider trained personnel, access to infrastructure, communication, available supplies, and broader system capacity. In regions that contain critical assets, the siting of a warehouse stocked with supplies can help ensure that parts are available. Equally important are trained personnel to implement needed repairs. Their successful deployment relies on access to damaged regions, requiring functional roads and equipment, as well as telecommunication and other services. An emergency response and preparedness plan that includes these considerations can enhance system resilience and broader institutional capacity. Many of the power projects in Sub-Saharan African countries have components for institutional capacity building, including a disaster risk management plan. Table 1 summarizes intervention areas for integrating climate resilience into energy sector projects.

Action Areas for Integrating Climate Resilience into Energy Sector Projects			
Step	**Intervention area**	**Purpose**	**Examples**
1.	Siting of infrastructure in less-exposed areas/adapting location design	Identifying expected historical stressors and projected climate change impacts by location	Systematic assessment of proposed infrastructure locations; geospatial analysis
		Adapting infrastructure to local geographical and climate risk factors	Elevate PV panels and other infrastructure assets, build flood walls; design siting of solar panels with wind direction in mind
			Design lines with aerial bundled cable and conductors in regions with high winds/fire risk
	Resilient infrastructure design and construction	Designing infrastructure and use of materials that increase resilience to extreme weather conditions	Provide appropriate anchorage support; deepen foundation and size of footings to adapt against extreme weather conditions; elevate control rooms and critical equipment to reduce flood hazard potential; use steel, concrete, or composite towers to resist high winds, floods or fires; use light-duty steel poles; waterproof key components
2.	Reduce liabilities and hazardous conditions created by infrastructure.	Mitigating risk to communities or external assets created by energy infrastructure under hazardous conditions	Designing lines with aerial bundled cable and conductors in high-risk regions; vegetation management and turning lines off at times of extreme risk.
3.	Increasing system redundancy	Providing alternative outlets if one connection fails	Densify and extend distribution networks
	Routine maintenance, and emergency backup generation options.	Enhancing system readiness to respond	Ensure access to the infrastructure and that ventilation systems are clean, free of debris, and adequate for cooling
4	Emergency response plans	Enhancing system resilience and broaden institutional capacity for emergency response	Readily available trained personnel, access to infrastructure, communication, available supplies, and broader system capacity

3. Case studies from the AFRI-RES–supported energy resilience sector projects on integrating resilience into designs

This section describes two projects[3] supported by the AFRI-RES fund. The first one, in Benin, will conduct a vulnerability analysis study financed by the AFRI-RES fund which will inform project design, including the detailed engineering design, location, and environmental management plan. The second, in the Democratic Republic of Congo, used the Resilience Booster tool to aid project design. The Resilience Booster is an interactive, step-by-step tool for development practitioners to embed climate resilience through a set of resilience attributes into project designs. It helps teams to think through, specify, and design project activities that build resilience by integrating resilience attributes. We report the results of the application of the Resilience Booster at the end of the project description if available.[4]

Energy poverty and access inequality make it more difficult for countries to achieve socioeconomic targets in health and education, and realize the full potential of human capital. It also increases their vulnerability to climate change, natural disasters and pandemics, because energy is an important input for water supply, sanitation, and broadband, as well as economic activity.

Benin Electricity Access Scale-up Project

The Benin Electricity Access Scale-up Project (US$ 200.00 million) is designed to respond to many of the sector challenges described previously. Energy poverty contributes to Benin's high level of vulnerability to the effects of climate change. Reducing energy poverty and inequality in the provision of energy services will reduce vulnerability to natural disasters and climate change and has important links to the climate change actions and policies in Benin's Nationally Determined Contribution (NDC). The project will support the Benin PROSPERE plan to expand distribution network to connect 780,000 households, 1,000 micro, small, and medium enterprises, and 500 public facilities. It will improve network resiliency by incentivizing the adoption of grid technical norms and standards through the use of performance-based conditions. It will boost network resiliency to climate risks by identifying risks and ensuring the infrastructure includes resilience measures (see figure 1). Thus, a climate vulnerability and resilience assessment for Benin will be considered in the project's engineering design to elaborate solid bidding documents for electrification works. The project will build on this analytical work by financing the identification and implementation of complementary civil works to ensure that the distribution networks to be densified and extended under the project are resilient to climate risks, such as seasonal flooding. Examples of possible resilience measures include (a) provision of appropriate anchorage support; (b) deep foundation and size

3 Greater Accra Climate Resilient and Integrated Development Project, Senegal Stormwater Management and Climate Change Adaptation Project II, Cameroon Douala Urban Mobility Project, Tanzania Development Corridors Transport Project, Tanzania Roads to Inclusion and Socioeconomic Opportunities (RISE) Project

4 See also Rigaud, Arora, and Singh (2023).

of footings to adapt against extreme weather conditions; (c) elevation of control rooms and critical equipment to reduce flood hazard potential; (d) use of steel, concrete, or composite towers; and (d) use of light-duty steel poles. Vegetation management will be considered during site selection to avoid risk of wildfires. Although the incremental cost of resilience measures can vary and can be properly estimated only after local assessments, it can range from 4 percent to 14 percent for some low-hanging measures. The recommendations of the Benin climate vulnerability and resilience assessment will inform the elaboration of these norms.

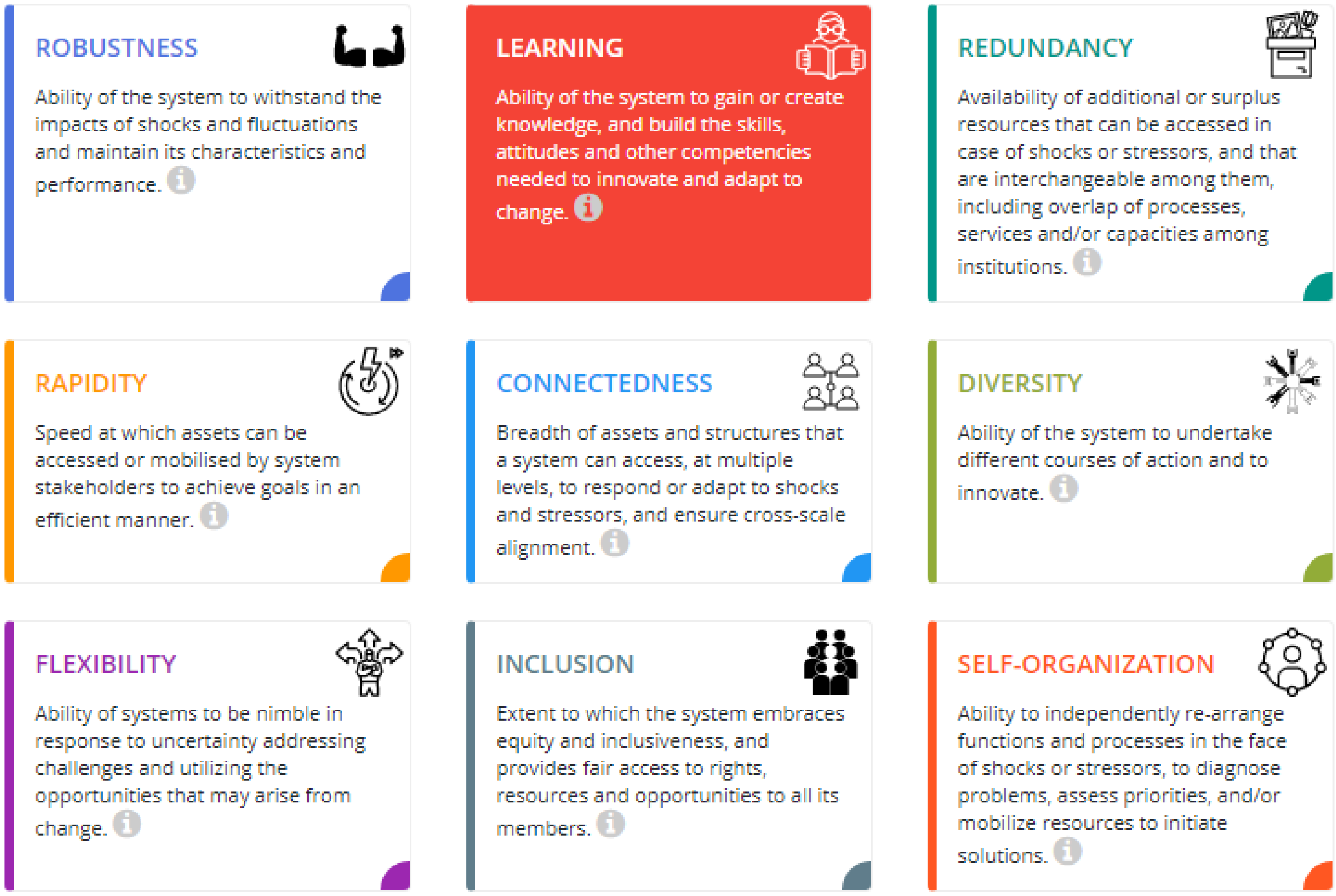
Democratic Republic of Congo Electricity and Water Access and Governance Project

The Democratic Republic of Congo Electricity and Water Access and Governance Project (US$ 634.00 million) will address climate vulnerabilities through developing climate-resilient power infrastructure. It will (a) enhance the design and protect power infrastructure from flooding and erosion (landslides); (b) support utilities with business continuity and preparedness measures; and (c) provide households and productive users with energy services, increasing adaptive capacities. Through provision of electricity access, community and households' resilience to extreme climate events will be improved. Through institutional strengthening and capacity building, climate change and adaptation planning will be integrated into development of planning, policy, legislative, and monitoring instruments and performance improvement measures.

The use of resilient infrastructure will help to prevent climate change–induced damage. Steel or concrete poles for grids (and possible isolated conductors) will increase their resistance to damage from flooding, high winds, wildfires and other hazards. Elevation of substations or other protective infrastructure will reduce the likelihood of inundation and resulting damages from flooding. Other measures include waterproofing electrical connections and elevating vulnerable equipment, such as panels.

Applying the Resilience Booster tool in its design, the project has increased robustness by its use of resilient infrastructure, including choice of materials for construction of assets, infrastructure siting, and O&M schedules. This in turn contributed to its **adaptation and absorptive** capacity. Through its **capacity building** on **risk management** and resilience of the central and provincial governments and the utility, it has increased response speed and its **adaptation**. Setting up **mobile electricity bill payment from customers and digitizing government agencies' bills** have increased the system's **flexibility** and its **adaptation and absorptive** capacity (figure 4 below).

Figure 4. Resilience Booster Tool Attributes.



Source: World Bank AFRI-RES webpage at: https://resiliencetool.worldbank.org/#/home

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