

ERF

# Policy Research Report

## Empowering Households in Fragile States: Leveraging MSMEs for Decentralized Electrification

Muez Ali

---

# Table of Contents

|                                                                                            |           |
|--------------------------------------------------------------------------------------------|-----------|
| <b>Table of Contents</b>                                                                   | <b>2</b>  |
| <b>List of Figures</b>                                                                     | <b>3</b>  |
| <b>Summary</b>                                                                             | <b>4</b>  |
| <b>1. Introduction</b>                                                                     | <b>5</b>  |
| 1.1. The challenge of energy poverty in fragile states                                     | 5         |
| 1.2. The Mission 300 Initiative                                                            | 5         |
| 1.3. Why MSMEs are the missing link                                                        | 6         |
| 1.4. Purpose and objectives: Guiding a research program                                    | 7         |
| 1.5. Report structure                                                                      | 7         |
| <b>2. The Sudanese context:<br/>    A case study in fragility and decentralized energy</b> | <b>8</b>  |
| 2.1. Macroeconomic performance                                                             | 8         |
| 2.2. Overview of Sudan's energy landscape                                                  | 12        |
| 2.3. Challenges posed by instability, economic crises and conflict                         | 13        |
| 2.4. Solar value chains                                                                    | 14        |
| 2.5. Renewable energy potential                                                            | 14        |
| 2.6. Solar energy in Sudan pre-conflict                                                    | 15        |
| 2.7. Sudan's solar PV imports                                                              | 18        |
| <b>3. The impact of the war on MSMEs</b>                                                   | <b>20</b> |
| 3.1. Energy access and costs                                                               | 20        |
| 3.2. Adaptive strategies and infrastructure gaps                                           | 21        |
| 3.3. The role of MSMEs in Sudan's economy                                                  | 22        |
| <b>4. Conclusion</b>                                                                       | <b>23</b> |

# List of Figures

|                                                                                        |    |
|----------------------------------------------------------------------------------------|----|
| Figure 1. Change in night lights between 2023 and 2025                                 | 9  |
| Figure 2. GDP growth and unemployment rates 2018 – 2023                                | 10 |
| Figure 3. GDP recovery path 2023 to 2028                                               | 10 |
| Figure 4. GDP sectoral decomposition                                                   | 11 |
| Figure 5. GDP growth by sector pre-, during and post-conflict in Sudan                 | 11 |
| Figure 6. Inflation rates in Sudan 2021 to 2025                                        | 11 |
| Figure 7. Money supply growth, inflation rate and exchange rates in Sudan              | 12 |
| Figure 8. Number of sampled households using different types of energy                 | 16 |
| Figure 9. Use of different energy types by region                                      | 17 |
| Figure 10. Proportion of households that use solar energy by region                    | 17 |
| Figure 11. Distribution of energy sources used by businesses                           | 18 |
| Figure 12. Solar PV exports to Sudan, Sub-Saharan<br>Africa average and global average | 19 |
| Figure 13. Solar PV imports in Sudan over time for the period 2017 to 2025             | 19 |
| Figure 14. Monthly solar capacity imports in Sudan                                     | 19 |
| Figure 15. The evolution of prices of solar PV imports in Sudan over time              | 19 |
| Figure 16. Annual imports of solar PV components by type of component                  | 19 |
| Figure 17. Total value of solar PV imports and cumulative capacity in Sudan            | 19 |

# Summary

More than 600 million people in Sub-Saharan Africa still lack access to electricity, and the deficit is most acute in fragile and conflict-affected states, where political risk, insecurity and weak utilities make grid expansion slow, costly and vulnerable. The falling cost of decentralized renewable energy, such as solar home systems, mini-grids and solar water pumps, offers a faster alternative, but only if there is a delivery model that can work in volatile, resource-scarce settings. This paper argues that, for immediate and short-term access, that model is a bottom-up one built on local micro, small and medium enterprises (MSMEs). It proposes an analytical framework and research agenda to inform the World Bank's Mission 300 initiative, which aims to connect 300 million people in Sub-Saharan Africa to electricity by 2030.

Sudan is used as the illustrative case. Since April 2023 the conflict has caused real GDP to contract by an estimated 29.4 percent in 2023 and a further 13.5 percent in 2024, while inflation reached 216 percent by December 2024 and the Sudanese pound fell to its lowest value against the US dollar in a decade. Before the war, national electrification stood at roughly 45 to 65 percent, with rural access often below 20 percent, and the grid (about 3,600 MW, concentrated along the Nile) has since suffered heavy damage. Following the removal of fuel subsidies in 2020 and 2021, and again in response to the conflict, households and businesses have turned to small-scale solar supplied by an informal, largely unregulated import market. Trade data show surges in solar PV imports in 2021 and again from 2024, with import prices falling by 73 to 85 percent between 2017 and 2025. Survey data from 2022, however, show that pre-war solar adoption was low and uneven: just over 7 percent of households in Khartoum, the highest of any region, and just over 0.5 percent of businesses.

Qualitative evidence from eight states, together with a 2024 IFPRI enterprise survey, shows that most MSMEs were operating at less than half their capacity by the end of 2024 because of power outages, fuel scarcity, broken supply chains and the collapse of bank lending. Micro and small enterprises, many of them women-owned, proved more resilient than medium-sized firms. Many MSMEs are shifting to solar, but adoption is held back by high upfront costs, expensive short-term credit (20 to 35 percent interest), concerns about equipment quality and warranties, a shortage of trained technicians, low awareness and limited government support.

The paper concludes that MSMEs, embedded in local trust and credit networks and able to handle distribution, installation and after-sales service where formal institutions fail, are the most credible last-mile delivery channel in fragile settings. It recommends that Mission 300 measure success by the resilience of this local delivery channel rather than by megawatts installed, and that it prioritize productive uses of energy by bundling income-generating appliances, such as solar water pumps and milling units, with decentralized systems so that customers can afford to pay. It identifies priority research areas (household demand and willingness to pay, MSME capacity mapping, energy gap analysis, regulatory and institutional reform, financing mechanisms, delivery-model scalability, productive use of energy and socio-economic impact) and positions Sudan as a pilot whose lessons could extend to other fragile states such as South Sudan, Yemen and the Democratic Republic of Congo.

## 1. Introduction

### *1.1. The challenge of energy poverty in fragile states*

The global challenge of energy poverty remains one of the most significant barriers to achieving sustainable development, particularly in sub-Saharan Africa. Despite decades of global efforts, ambitious targets and investment, over 600 million people in Sub-Saharan Africa still lack access to electricity.<sup>1</sup> The consequences of this deficit are systemic, they undermine progress in health, education and economic growth. Energy is an enabler of at least two-thirds of the SDG targets.<sup>2</sup> Households reliant on traditional and inefficient fuels, such as kerosene and biomass, are trapped in a cycle of low productivity and high incidence of respiratory illness. And businesses operating in contexts of low access to electricity and aging infrastructure struggle due to unpredictable power supply.<sup>3</sup>

The challenges of energy poverty and access are not evenly distributed. Fragile and conflict-affected states (FCS) – characterized by protracted political instability, weak state capacity and degrading infrastructure – are disproportionately affected by energy poverty.<sup>4</sup> In fragile contexts, the drivers of energy poverty are amplified. Political risk deters large-scale, long-term investment necessary for centralized grid expansion.<sup>5</sup> Active conflict and insecurity make construction and maintenance of grid infrastructure dangerous and expensive. Furthermore, the institutional weakness of national utilities and regulatory bodies means that even

when infrastructure is theoretically in place, service delivery is often fragmented, unreliable and non-existent outside of major urban centers.<sup>6</sup>

The rapid decline in the cost of decentralized renewable energy solutions, such as solar home systems and mini-grids, has introduced a contested yet viable alternative. Decentralized systems bypass the need for large, centralized infrastructure, are modular and can be rapidly deployed at the point of need.<sup>7</sup> But while decentralized systems are often celebrated for their flexibility and lower initial capital expenditure compared to grid extension, their success in fragile contexts is not guaranteed. Deploying decentralized systems requires stable local supply chains, local maintenance capacity, affordable financing for last-mile consumers and a regulatory environment that supports broader participation.<sup>8</sup> Therefore, the essential question for short-term electrification efforts that aim to address immediate needs is not whether decentralized renewable energy technology is appropriate, but which model of delivery can succeed in volatile and resource-scarce environments. The answer may lie in local capacity, specifically in the resilient ecosystem of Micro, Small, and Medium Enterprises operating in and around the sector.

### *1.2. The Mission 300 Initiative*

Scaling decentralized solutions to meet electricity needs in Sub-Saharan Africa has proven to be a significant challenge for the broad set of ambitious continental targets. The World Bank claims that the Mission 300 Initiative is a direct response to these challenges. The initiative set a goal to connect 300 million people to electricity in Sub-Saharan Africa by 2030.

The Mission's mechanisms to deliver this mandate are multi-faceted. While the objective is broad, there is a focus on mobilizing capital, de-risking and developing

<sup>1</sup> IEA, IRENA, UNSD, World Bank, WHO. 2025. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC. World Bank.

<sup>2</sup> Nerini, F. et al. 2018. Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nature Energy* 3: 10-15. <https://doi.org/10.1038/s41560-017-0036-5>

<sup>3</sup> Al Kez, D. et al. 2024. Energy poverty assessment: Indicators and implications for developing and developed countries. *Energy Conservation and Management* 307: 118324.

<sup>4</sup> Sacchetto, C. et al. 2020. Priorities for renewable energy investment in fragile states. LSE Research Online Documents on Economics 111549, LSE, LSE Library.

<sup>5</sup> Falchetta, G. et al. 2022. Harnessing finance for a new era of decentralized electricity access: A review of private investment patterns and emerging business models. *Energy Research and Social Science* 90: 102587.

<sup>6</sup> Gregory, J. and Sovacool, B. 2019. Rethinking the governance of energy poverty in Sub-Saharan Africa: Reviewing three academic perspectives on electricity infrastructure investment. *Renewable and Sustainable Energy Reviews* 111: 344-354.

<sup>7</sup> Carabajal, A.T. et al. 2024. Social and economic impact analysis of solar mini-grids in rural Africa: a cohort study from Kenya and Nigeria. *Environmental Research: Infrastructure and Sustainability* 4: 025005.

<sup>8</sup> Dagnachew, A.G. 2020. Actors and governance in the transition toward universal electricity access in Sub-Saharan Africa. *Energy Policy* 143: 111572.



an enabling environment for investments. Some of the mechanisms include broad-based policy engagement to streamline national regulatory processes, the creation of innovative funding facilities to pool public and private capital and the development of standards and quality controls for off-grid technologies to achieve economies of scale. Mission 300 also aims to focus on decentralized solutions for contexts where centralized grids are costly and potentially unreliable. This is precisely the context in fragile states. The initiative acknowledges the limitations of a one-size-fits-all approach and promotes context-specific solutions. This approach recognizes that challenges under political instability – as is the case in Sudan today – are fundamentally different from those in a more stable context.

There is significant overlap between Mission 300's mandate and the unique conditions in fragile states. By targeting the hardest-to-reach populations, the program targets the infrastructural deficiencies exacerbated by fragility. However, this commitment may introduce significant challenges. The high transaction costs, lack of reliable market data, currency volatility and security risks inherent in fragile contexts threaten to undermine even the most well-capitalized efforts. Furthermore, there is an inherent electricity access-development trade-off in decentralized solutions. While decentralized solutions provide rapid, foundational lighting and charging, providing the energy needs for long-term development – powering large-scale industry or fully electrifying major institutions – would still require grid expansion in the future. Therefore, decentralized solutions must be viewed as a transitional development pathway that addresses immediate needs, may build local economic capacity and prepare communities for future grid integration. The Mission's success in fragile contexts will depend on whether it can effectively operationalize a delivery model that is robust enough to navigate fragility yet flexible enough to scale.

### *1.3. Why MSMEs are the missing link*

Traditional, top-down approaches to energy infrastructure development have a well-documented history of failure in fragile and conflict-affected states.<sup>9</sup> During conflict, large, capital-intensive utility projects are vulnerable to security risks, where infrastructure is often weaponized or destroyed. The high operational costs of utility scale energy infrastructure and cost

<sup>9</sup> Shettima, A. et al. 2023. The impact of conflict on energy poverty: Evidence from Sub-Saharan Africa. *Resources Policy* 86(Part A): 104090; Khalid, U. et al. 2024. Does conflict aggravate energy poverty? *Energy Policy* 194: 114317.

recovery challenges in weak institutional and low tax efficiency environments make investments fiscally unsustainable and politically fraught.<sup>10</sup> Moreover, external development partners often overlook or misunderstand the nuances of the local political economy.<sup>11</sup> This can lead to projects that are designed in isolation and collapse once international funding ceases.<sup>12</sup>

The core proposition in this report is that, for the purposes of providing immediate, short-term access to energy, a new, bottom-up approach, centered on leveraging the experience and resilience of local MSMEs, presents an opportunity to overcome the chronic last-mile delivery challenges that plague traditional models. MSMEs, by their nature, are embedded in the local communities within which they operate. This grants them several advantages:

- **Resilience and adaptability:** MSMEs operate within informal economies, which requires them to navigate and adapt to instability and supply chain disruptions. They often achieve this through localized networks and trust-based relationships. They have experience and develop expertise in operating in high-risk environments where larger firms would tend to struggle.
- **Market knowledge:** MSMEs possess granular knowledge of household and local market energy demand, capacity to pay and the local socio-cultural dynamics that influence technology adoption.
- **Last-mile service delivery:** MSMEs are well positioned to handle the operational mechanics of decentralized energy – distribution, installation, after-sales service and maintenance – tasks that a centralized utility in a fragile context may not be able to manage.

By integrating MSMEs – both those currently operating in the energy sector (for example, importers, service providers, distributors and installers) and those that are not (for example, grocery shops, repair shops and agricultural MSMEs) – into a decentralized renewable energy value chain and into localized institutional structures, Mission 300 can effectively decentralize risk,

<sup>10</sup> Huenteler, J. et al. 2020. Cost Recovery and Financial Viability of the Power Sector in Developing Countries: Insights from 15 Case Studies. World Bank Policy Research Working Paper No. 9136. Washington, D.C.: World Bank.

<sup>11</sup> Sovacool, B. 2012. The Political Economy of Energy Poverty: A Review of Key Challenges. *Energy for Sustainable Development* 16: 272-282; Ferral, I. 2021. The Role of Political Economy in Energy Access: Public and Private Off-Grid Electrification in Tanzania. *Energies* 14(11): 3173.

<sup>12</sup> Perros, T. et al. 2022. Lost learnings: Breaking the silence of failure in the energy and development sector. *Energy Research and Social Science* 92: 102804.



decentralize operations and maximize adoption. This bottom-up approach is a service delivery mechanism and a means to influence broader infrastructure decisions by demonstrating commercially viable energy provision in locations previously deemed impossible. This approach ensures sustainability by building a local private-sector ecosystem on top of existing community-level institutions, both with an interest in maintaining and expanding service delivery.

#### *1.4. Purpose and objectives: Guiding a research program*

The purpose of this report is to provide an analytical framework for addressing the specific challenges and opportunities of leveraging MSMEs for decentralized electricity access in fragile and conflict contexts, presenting Sudan as a potential illustrative case study. Sudan's protracted conflict and fragility, persistent energy deficit and resilient and dynamic informal economy make it an appropriate – and potentially challenging – testing ground for new models of expanding access to electricity.

One specific objective of this report is to inform the design of a targeted, evidence-informed research program for Mission 300 in fragile and conflict settings by addressing the following key research areas:

- Household demand and capacity: What methodologies can be developed to accurately assess current and future household energy demand (lighting, charging, productive activities) and capacity – and willingness – to pay for different tiers of decentralized energy services?
- Mapping and evaluation of MSMEs: What is the best practical approach to map, evaluate and categorize the capacity of the local MSME ecosystem – for energy and non-energy sector firms – in terms of technical skills, business processes and financial readiness for delivering decentralized energy services?
- Energy gap analysis: It is important to undertake a quantitative assessment of the energy sector and energy demand in Sudan, with specific disaggregation into grid and existing off-grid supply levels. This analysis will define the role – in terms of what is practically feasible – of MSMEs in bridging this deficit.
- Regulatory and institutional support: How can national and local regulatory and institutional frameworks be designed – or reformed – to support, rather than burden, MSME participation in the energy sector (for example, streamlining import duties, establishing clear licensing procedures, allowing

for cooperatives and more adaptive public-private collaborations)?

- Financing mechanisms: What are the most effective, replicable and low-risk financing mechanisms for both last-mile consumers (for example, less exploitative Pay-As-You-Go/mobile money) and MSMEs operating in the sector (for example, access to working capital)?
- Delivery model scalability: How can the diverse MSME-led delivery models (for example, direct-to-consumer, cooperative, utility-managed partnerships) be evaluated for operational effectiveness, financial scalability and long-term sustainability?
- Promoting Productive Use of Energy (PUE): How can productive and monetizable uses of energy be identified, promoted and integrated into decentralized energy system deployment strategies to maximize capacity to pay for electricity services and achieve broader socio-economic benefits?
- Measuring socio-economic impact: How does increased, reliable electricity access enabled by MSMEs contribute to measurable outcomes in job creation, income generation, health (for example, clean indoor air, medicine refrigeration) and educational attainment?

#### *1.5. Report structure*

This report begins with the broad challenge of achieving universal access to electricity in Sub-Saharan Africa and then narrows to an analytical framework and research agenda for informing Mission 300 activities in fragile and conflict settings in the region. Following this introductory section, which also sets out the key research areas, Section 2 presents Sudan as an illustrative case. It reviews the country's macroeconomic performance since the outbreak of conflict, its energy landscape and institutions, the challenges posed by instability and economic crisis, gaps along the solar value chain, and the country's renewable energy potential, drawing on survey data on pre-conflict solar use and trade data on solar PV imports. Section 3 examines the impact of the war on MSMEs, covering energy access and costs, the adaptive strategies firms have adopted and the barriers they face in shifting to solar, and the structural role of MSMEs in Sudan's economy and their advantages as last-mile energy providers. Finally, Section 4 concludes with lessons for Mission 300, including recommendations to measure success by the resilience of the local MSME delivery channel and to prioritize productive uses of energy, and positions Sudan as a pilot for other fragile contexts.



## 2. The Sudanese context: A case study in fragility and decentralized energy

The selection of Sudan as a case study for informing Mission 300's strategy in fragile states is motivated by the country's prolonged experience with various drivers of fragility: political instability, systemic economic collapse and protracted conflict. Persistent economic and political instability has exacerbated energy poverty and dismantled traditional mechanisms for infrastructure development. However, these same conditions have caused a recent surge in the demand and adoption of decentralized renewable energy systems. These developments make Sudan an appropriate context for testing the viability of decentralized, MSME-led models for expanding access to electricity. Understanding the constraints within the Sudanese context is the first step in designing an effective research program.

### 2.1. Macroeconomic performance

The ongoing conflict in Sudan resulted in the collapse of the Sudanese economy. The conflict effectively erased the progress made over the two years prior to the conflict. Since 2018, Sudan's economy had been affected by political instability, beginning with the popular protests in December 2018 and regime change April 2019.<sup>13</sup> This was followed by a fragile and ultimately unsuccessful political transition between 2019 and 2021, which ended with a military coup in October 2021.<sup>14</sup> The coup disrupted an economic reform process and halted Sudan's progress toward qualifying for debt relief under the Heavily Indebted Poor Countries (HIPC) initiative, which could have led to reduction in external debt through arrears clearance and restructuring.<sup>15</sup> Since the start of the conflict, real GDP is estimated to have declined by 29.4 percent in 2023 and further contracted by an additional 13.5 percent in 2024.<sup>16</sup> The decline in economic activity in Sudan's major economic hubs,

Khartoum and Gezira, can be seen from changes in night time lights (Figure 1). There's a palpable decline in economic activity in the center and an increase in economic activity in the states in the north of Sudan along the Nile and in Port Sudan.

A large proportion of the country's productive capacity was destroyed as fighting transformed major cities including Khartoum, Wad Madani, El-Fashir, and Nyala, into war zones.<sup>17</sup> The spread of conflict to safe states disrupted economic activity, increased transportation costs, limited access to agricultural inputs, and interrupted the country's foreign trade.<sup>18</sup> The sectoral breakdown of the crisis reveals the scale of damage.<sup>19</sup> The agriculture sector, long a backbone of Sudan's economy, contracted by 14.9 percent in 2023 and 7.6 percent in 2024, contributing four percentage points to GDP decline in 2023.<sup>20</sup> The services sector, the largest contributor to GDP prior to the crisis, shrank by 43.2 percent in 2023 and 22 percent in 2024, driven by the destruction of public services in several states and the capital city.<sup>21</sup> Industry decreased by 25.8 percent in 2023 and 13.1 percent in 2024, reflecting the widespread destruction of factories and decline in industrial activity, particularly in Khartoum.<sup>22</sup>

Despite the devastation caused by the ongoing conflict, a gradual recovery was anticipated beginning in 2025, contingent on improvements in the security situation, the restoration of trade and investment flows, reconstruction of key infrastructure, and the revival of institutional functions.<sup>23</sup> Real GDP is projected to begin recovering modestly in 2025, with growth gradually increasing to 4 percent by 2028. Over the 2025 – 2028 period, the economy is expected to grow at an average annual rate of 3.1 percent, supported by contributions from the services sector (1.6 percentage points), agriculture (0.7), and industry (0.8).

<sup>13</sup> Hassan, M. and Kodouda, A. (2019), Sudan's uprising: the fall of a dictator, *Journal of Democracy* 30(4): 89-103.

<sup>14</sup> Ali, M. et al. (2024), Conditionality Breeds Contempt: Donor and Multilateral Myopia in Sudan, *African Studies Review* 67(4): 863-887.

<sup>15</sup> Elbadawi, I. et al. (2023), Post-Conflict Reconstruction, Stabilization and Growth Agenda for Sudan, Finance for Development Lab Policy Note 13. Available on: [https://findevlab.org/wp-content/uploads/2023/11/FDL\\_ERF\\_Sudan\\_Paper.pdf](https://findevlab.org/wp-content/uploads/2023/11/FDL_ERF_Sudan_Paper.pdf)

<sup>16</sup> World Bank (2025), Sudan Economic Update. The Economic and Social Consequences of the Conflict: Charting a Path to Recovery, Washington DC: World Bank. Available on: <https://documents1.worldbank.org/curated/en/099051925180542315/pdf/P178527-6a7d4d70-52be-49b7-87e5-ead89050a99b.pdf>

<sup>17</sup> Siddig, K. (2025), Sudan's war is an economic disaster: Here's how bad it could get, IFPRI Blog: Research Post, Development Strategies and Governance. Available on: <https://www.ifpri.org/blog/sudans-war-is-an-economic-disaster-heres-how-bad-it-could-get/>

<sup>18</sup> Siddig (2025).

<sup>19</sup> Conflict and Environmental Observatory (2025), The environmental costs of the war in Sudan. Available on: <https://ceobs.org/the-environmental-costs-of-the-war-in-sudan/>

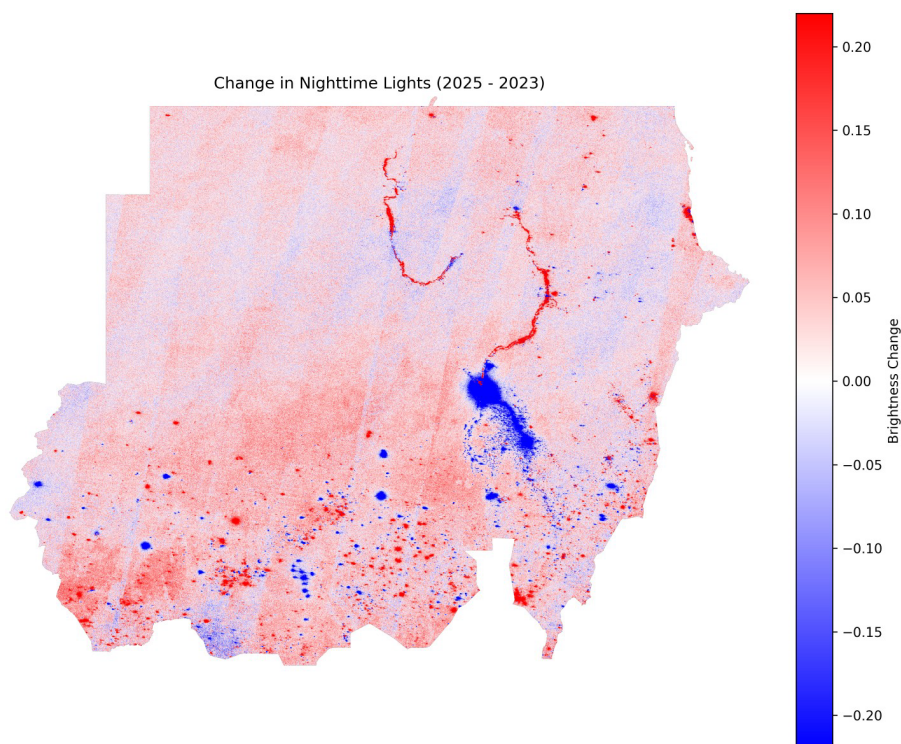
<sup>20</sup> World Bank (2025), p. 21.

<sup>21</sup> World Bank (2025), p. 21.

<sup>22</sup> World Bank (2025), p. 21.

<sup>23</sup> See Part 1: Recent Economic Developments and Medium-Term Outlook in World Bank (2025).



*Figure 1. Change in night lights between 2023 and 2025*

*Note: blue color indicates a decrease in light intensity, red color indicates an increase in light intensity*

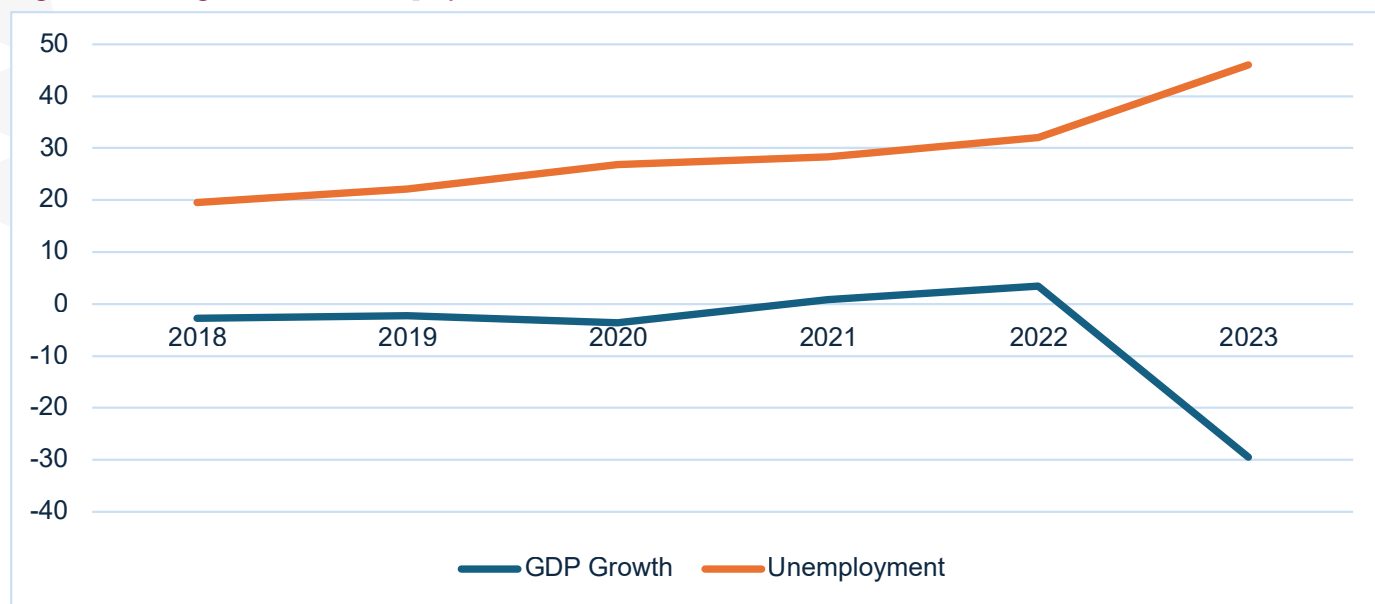
The composition of the economy is also expected to shift. The services sector, which accounted for 52 percent of GDP between 2019 and 2022, is projected to decline to 45.5 percent of GDP between 2023 and 2026, reflecting the collapse of urban centers and government service delivery (see Figure 4). Agriculture, which contributed 27 percent of GDP during the same pre-conflict period, is expected to rise to 34 percent as a share of GDP, primarily due to the relative decline of other sectors rather than an expansion in agricultural output. Industry is projected to see a decline in its share of GDP from 22 percent (2019 to 2022 average) to 20.7 percent during 2023 to 2026, reflecting the destruction of production facilities and disruption of supply chains. These projections are highly sensitive to political and security developments, and the pace and scale of reconstruction efforts.

Sudan has been suffering from high inflationary pressures. Inflation rates peaked during the COVID-19 pandemic in June 2021 after removal of fossil fuel subsidies and unification of the exchange rate between September 2020 and February 2021. A range of policy measures helped curb inflation, which started to decline gradually, reaching 87 percent by the end of December 2022. At the beginning of 2023, inflation continued to fall, reaching 48 percent by March — just one month

before the outbreak of the conflict, which reversed the downward trend and drove prices back up. Inflation rates gradually increased to 93 percent by December 2023, then surged to 216 percent by December 2024, before another decline.

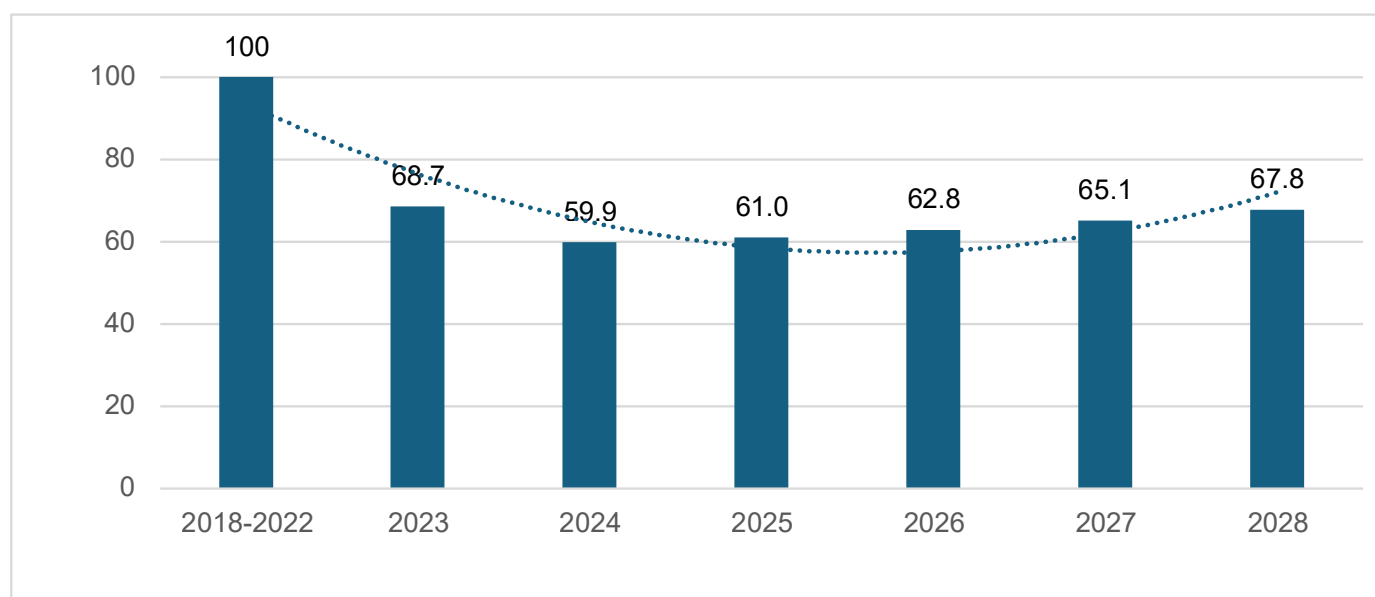
This volatile pattern could be attributed to several factors. Some of these factors include increases in rent for housing, especially in states that received large numbers of internally displaced people fleeing the conflict, increased demand for transportation amid fuel shortages, and the shutdown of key infrastructure in the oil sector. Disruptions in imports and higher food prices also contributed to inflation (see Figure 6). The disruption of economic activity limited the state's capacity to collect taxes. The government resorted to printing money to finance rising public spending. Exchange rate shock also fueled inflation by raising the cost of imports and the collapse of the Sudanese pound to its lowest value against the US Dollar in the last decade (Figure 7). The depreciation in exchange rates is driven by several factors including deficit financing, a decline in exports, an increase in financial transfers to families that fled to neighboring countries, redirection of a high portion of remittances to neighboring countries and an increase in demand for foreign currency to import military equipment.

Figure 2. GDP growth and unemployment rates 2018 – 2023



Source: Central Bank of Sudan (2024), Economic Development in Sudan Report 2023. Port Sudan: Central Bank of Sudan

Figure 3. GDP recovery path 2023 to 2028

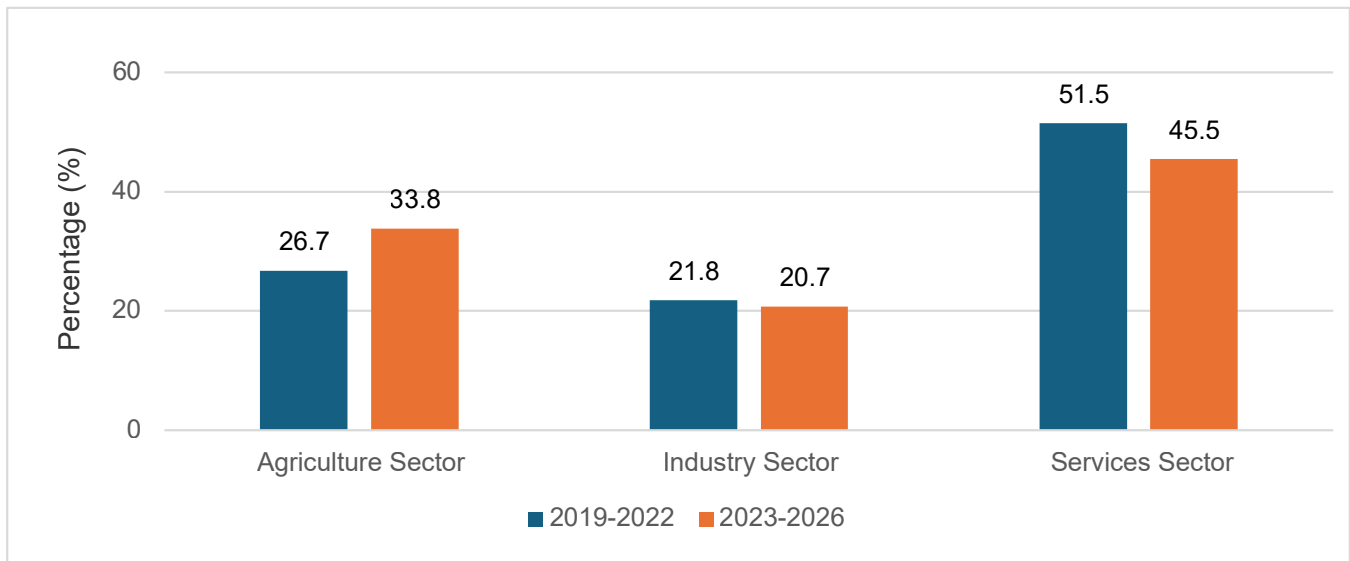


Source: Central Bank of Sudan (2024).

Note: the authors calculated the average GDP for the period 2018 to 2022 to reflect pre conflict performance. Then, using this figure, the ratio of GDP for each year in the period 2023 to 2028 is divided by this average to show the gap between the pre conflict GDP level and the projections until 2028

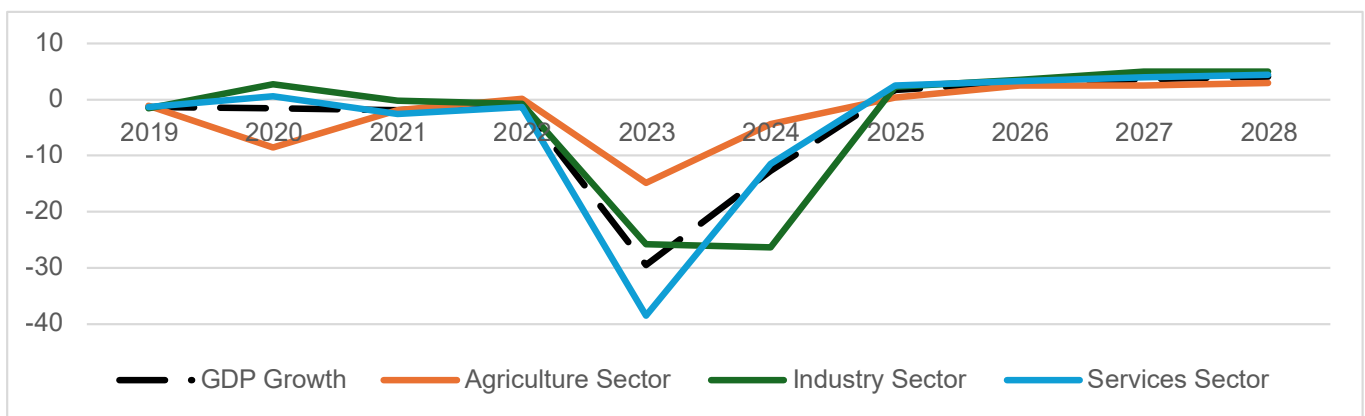


Figure 4. GDP sectoral decomposition



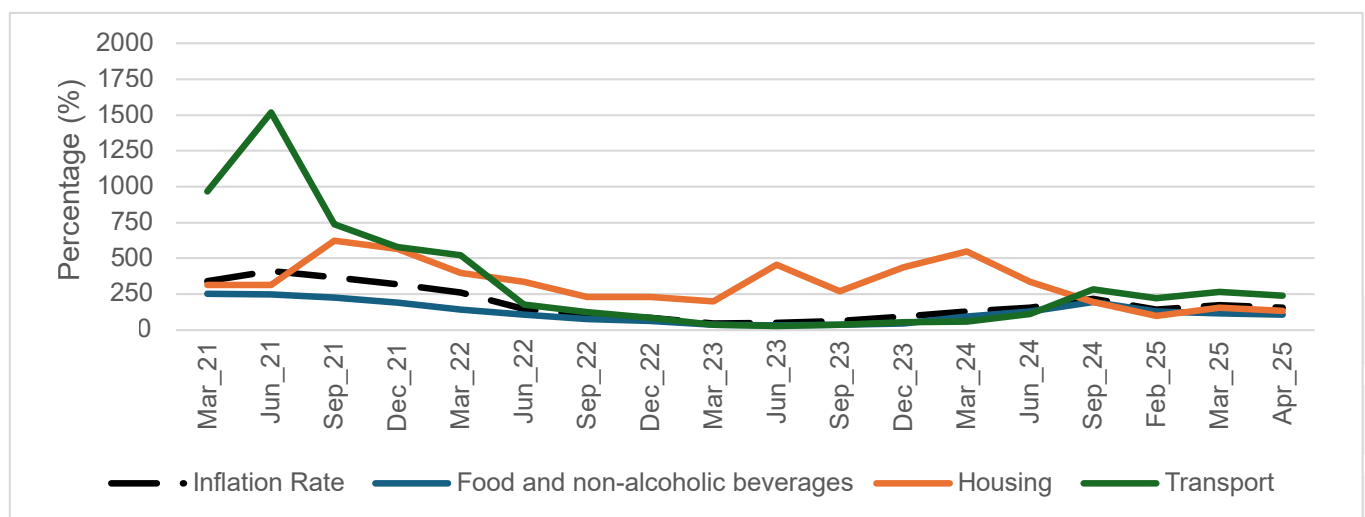
Source: Central Bank of Sudan (2024).

Figure 5. GDP growth by sector pre-, during and post-conflict in Sudan 2019 to 2028



Source: Central Bank of Sudan (2024).

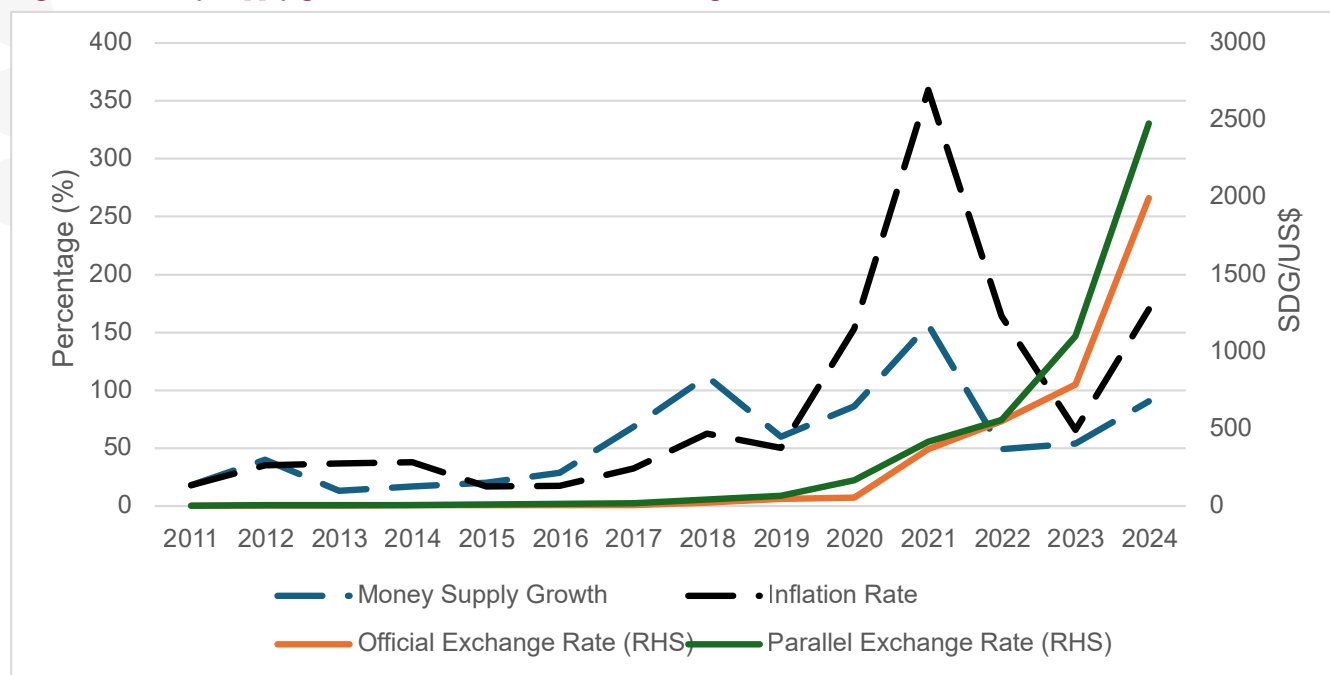
Figure 6. Inflation rates in Sudan 2021 to 2025



Source: Central Bank of Sudan (2024).



Figure 7. Money supply growth, inflation rate and exchange rates (RHS) in Sudan 2011 to 2020



Source: Central Bank of Sudan (2024), Central Bureau of Statistics (2024)

## 2.2. Overview of Sudan's energy landscape

Sudan's energy landscape is defined by two factors: reliance on aging, centralized infrastructure and a low rate of electricity access – particularly in rural and conflict-affected areas.<sup>24</sup> Prior to the resurgence of conflict in April 2023, the electrification rate in Sudan ranged from 45% to 65% at the national level.<sup>25</sup> This figure masks regional and socio-economic disparities. In urban centers, access rates are relatively higher – sometimes exceeding 80% in Khartoum and other major cities – while in rural areas, where the majority of the population lives, access is often lower than 20%.

The Electricity Act of 2001 is the legal framework on which the sector operates. At the time National Electricity Corporation was created as the sole generator, transmitter and distributor of electricity.<sup>26</sup> The Electricity Regulatory Authority (ERA) was set up as independent

regulator. A new horizontal structure was introduced in 2010. This structure was later updated in 2016 to create the Sudanese Electricity Holding Company to manage the sector through the SHGC, STPG, SETC and SEDC.<sup>27</sup> In 2018, the SHGC's responsibilities were expanded to include other forms of renewable energy generation including wind and solar. Until April 2023, the five sector organizations (SHGC, STPG, SETC, SEDC and SEHC) were institutionally embedded within the Ministry of Water Resources, Irrigation and Electricity (MWRIE).

This institutional set up has recently been updated after the start of the conflict in 2023. Under the new structure, the SEHC and other state owned enterprises operating in the energy sector, such as the Sudanese Petroleum Corporation, and the Electricity Regulatory Authority now operate under the Ministry of Energy. The Ministry of Energy now includes a Directorate of Energy Affairs, which, with the support of the Directorate of Energy Information and Statistics, is responsible for developing the National Energy Plan, proposing new policies, and assessing demand, supply and forecasts.

The national grid, operated by the Sudanese Electricity

<sup>24</sup> Mohammed, A. et al. 2025. Electricity Access Linkages to Sustainable Development Goals in Rural Sudan. Sustainability 17(6): 2441.

<sup>25</sup> This actual value is elusive; the range is reflective of the figures available in the literature. For example, the World Bank's World Development Indicators database puts this figure at 63% in 2022. See World Bank. 2025. World Development Indicators: Access to Electricity (%). Washington, D.C.: World Bank.

<sup>26</sup> Ali, M. et al. 2024. The Role of MSMEs in Fostering Inclusive and Equitable Sustainable Economic Development: Sudan Case Study. ERF Policy Research Report No. 52. Cairo: Economic Research Forum.

<sup>27</sup> SHGC is the Sudanese Hydropower Generation Company, STPG is the Sudanese Thermal Power Generation company, SETC is the Sudanese Electricity Transmission Company and SEDC is the Sudanese Electricity Distribution Company.



Distribution Company (SEDC), provides electricity mainly from hydropower and thermal power plants, for a pre-conflict installed capacity of approximately 3,600 MW. Generation capacity has not kept up with demand, which leads to consistent and unpredictable load. The grid infrastructure is concentrated along the Nile corridor, leaving massive areas – especially in Darfur, Kordofan and much of the Eastern and Southern regions – either completely off-grid or reliant on diesel generator off-grid systems.<sup>28</sup> This failure to achieve universal coverage via the grid is not merely an engineering problem; it is a political and economic one.

### *2.3. Challenges posed by instability, economic crises and conflict*

Protracted conflict has long been a barrier to energy infrastructure development in Sudan. Political instability, marked by successive coups, fleeting democratic transitions and prolonged periods of sanctions have undermined investment in infrastructure.<sup>29</sup> Good governance and predictable policies are the most salient factors that determine investment decisions for international investors and multilateral banks support private sector development.<sup>30</sup> This often means that national utilities in fragile contexts have to rely on local underdeveloped capital markets or state subsidies. Policy uncertainty prevents the formulation and enforcement of coherent, long-term energy strategies. The persistent economic crises have similarly debilitating impacts. Sudan has endured chronic inflation and severe shortages of foreign currency over the past 5 years.<sup>31</sup> As a consequence, imports of spare parts for thermal plants and new equipment are expensive and prices are unstable. Today, the current

conflict has had direct impacts on energy infrastructure.<sup>32</sup> Power plants, substations and transmission lines have become strategic targets or collateral damage. In regions with the highest intensity of conflict, there are consistent power outages.

As a consequence of the persistent power outages, policy changes in 2020 and 2021, and to satisfy growing demand for electricity, an informal, decentralized energy sector has emerged. Private generators, a pervasive and expensive alternative to the national grid, are widespread in urban areas and among large businesses. Since the first quarter of 2021, initially due to fossil fuel subsidy removal and more recently due to the conflict, Sudanese households and small businesses started to adopt small-scale solar solutions.<sup>33</sup> Today, this market is driven by small, often unregulated, private traders importing the different components that make up generator and solar PV systems. Imports come mainly from China. The proliferation of cheap, non-standardized components without warranties have led to early failure in some instances. Furthermore, a lot of these systems rarely provide enough power for productive uses.

One productive use of solar systems, solar water pumping, represents one of Sudan's most successful decentralized uses of energy. After the economic reforms of 2021, solar water pumping has shown consistent commercial viability. Its success is due to a clear economic incentive: replacing expensive diesel pumps and volatile fuel inputs. While the sector does not enjoy a stable regulatory environment, before the conflict, agricultural supply chains were relatively stable and predictable.

The existing decentralized energy solutions, while resilient, are fragmented and lack the financial and technical ecosystem required for them to scale. The supply chain has a diverse set of actors, with some firms having accumulated several years of experience in the sector while others are recent entrants. The lack of credit from the local banking system due to the recent conflict may limit the introduction of models that require mobile money integration or other fintech solutions. This is where the strategic involvement of MSMEs becomes important: they represent a structure that has the potential to formalize and scale this organic, informal market that has persisted despite Sudan's context.

<sup>28</sup> Usui, K. et al. (2019), From Subsidy to Sustainability: Diagnostic Review of Sudan Electricity Sector, Washington D.C.: World Bank Group. Available at: <http://documents.worldbank.org/curated/en/486961588608080192/From-Subsidy-to-Sustainability-Diagnostic-Review-of-Sudan-Electricity-Sector>

<sup>29</sup> Elbadawi, I. et al. (2023), Post-Conflict Reconstruction, Stabilization and Growth Agenda for Sudan, ERF Working Paper Series No. 166, Cairo: Economic Research Forum.

<sup>30</sup> World Bank (2020). Global Investment Competitiveness Report 2019/2020. Washington, D.C.: World Bank.

<sup>31</sup> Ali et al. 2024.

<sup>32</sup> Ali, A. H. and Ali, M. 2025. Rebuilding Sudan's Energy Sector: Pathways to Equitable Post-Conflict Recovery. Middle East Council on Global Affairs Issue Brief. Available on: <https://mecouncil.org/publication/rebuilding-sudans-energy-sector-pathways-to-equitable-post-conflict-recovery/#:~:text=The%20country%20has%20an%20installed,1%25%20of%20the%20power%20mix.>

<sup>33</sup> Ali et al. 2024.



## 2.4. Solar value chains

Several critical gaps exist along the solar value chain in Sudan. Virtually all components of solar PV systems (panels, inverters, batteries) are imported. This is a challenge exacerbated by prevailing macroeconomic issues, primarily limited foreign currency in the domestic market, high inflation rates and persistent devaluation. Logistical bottlenecks at the port – made worse since the start of the conflict – introduce significant delays. These factors result in high capital requirements for SMEs operating in the sector, which raises entry barriers, and high upfront costs for consumers – the upfront capital cost is consistently cited as the most significant barrier to adoption for households and SMEs.<sup>34</sup>

Another gap is in the distribution, installation and after-sales networks for solar PV. This is especially problematic outside of major cities. Renewable energy market has historically been concentrated in Khartoum and a few urban centers, which means that rural and peripheral regions are underserved.<sup>35</sup> There is also a shortage of trained technicians and service providers accessible to remote communities. The lack of access to maintenance services for rural consumers is likely to have dented confidence and perceptions of reliability. Moreover, data on resource potential, market players and performance of renewable energy systems in Sudan is scattered and not consolidated.<sup>36</sup> Awareness of solar/wind solutions among the general population is limited outside pilot projects. Past donor programs often stayed at the pilot stage and were not scaled up or replicated, leading to slow diffusion of knowledge.

Institutional and human capacity gaps also persist throughout the value chain. While a Renewable Energy Department existed for a long time within the Ministry of Energy and Mining, other government agencies have limited technical capacity on the sector to design bankable projects or to regulate and integrate renewables – for example, there are no standardized

grid connection procedures for IPPs.<sup>37</sup> Coordination between stakeholders is weak – for instance, the absence of a dedicated renewable energy agency means no single body is championing policy implementation or convening private sector actors.<sup>38</sup> On capacity across the supply chain, there is limited knowhow and expertise on regulating, financing and implementing large-scale projects. For example, Sudanese banks lack the expertise to appraise renewable energy investments. Meanwhile, security and conflict-related disruptions have recently created a new category of value chain gaps. Many solar companies are small businesses themselves and like other SMEs, they face liquidity issues, rising costs and physical risks in conflict zones.

All these gaps point to the need for an integrated value-chain approach. Developing Sudan's renewable energy sector requires addressing several aspects simultaneously in a cohesive strategy: logistical bottlenecks, skills and expertise, financing and market access. By identifying where the bottlenecks are (for example, the availability of certified solar installers or the supply of quality components) and who the key actors are (informal traders, cooperatives and NGOs active in the energy space), interventions can target the weakest links in the chain.

## 2.5. Renewable energy potential

Despite significant supply gaps and structure challenges – including weak policies and regulations, limited market data, inadequate local technical capacity, restricted access to financing and underdeveloped research and development – Sudan's solar energy sector has seen significant growth in recent years.<sup>39</sup> Key milestones include: the commissioning of Al-Fashir 5 MW solar facility, Sudan's first utility-scale project; the 54 MW privately owned solar PV facility at the Shamal Cement Factory, currently the largest of its kind; and the approval of a net-metering framework alongside the launch of a pilot scheme. The market has also seen rapid growth in solar-powered water pumping projects. These developments have benefited from policy reforms such

<sup>34</sup> Ali, M. et al. 2024. The Energy Transition and MSMEs in Sudan: Limitations and Opportunities. ERF Policy Brief No. 142. Available on: <https://erf.org.eg/publications/the-energy-transition-and-msmes-in-sudan-limitations-and-opportunities/>

<sup>35</sup> Bashier, R. and Salah, M. 2022. The electricity crisis in Sudan: Between quick-fixes and opportunities for a sustainable energy transition. TNI Longreads. Available on: <https://www.tni.org/en/article/the-electricity-crisis-in-sudan>

<sup>36</sup> Alhaj, M. 2020. Developing the enabling environment for renewable energy in Sudan. Clean Energy 4 Africa.

<sup>37</sup> UNDP. 2020. Empowering Sudan: Renewable Energy Addressing Poverty and Development; Ali et al. 2024.

<sup>38</sup> Alhaj. 2020.

<sup>39</sup> Abdalla, M. and Qarmout, T. 2023. An analysis of Sudan's energy sector and its renewable energy potential in a comparative Africa perspective. International Journal of Environment Studies 80(4): 1169-1187.



as the Investment Law of 2021.<sup>40</sup> Additional measures – including gradual removal of electricity tariffs and fuel subsidy reforms, the establishment of a solar component quality testing laboratory in 2020<sup>41</sup> and the expansion of private sector financing partnerships – indicate an emerging, though still fragile, foundation for scaling solar deployment in Sudan.

Sudan possesses vast solar and wind resources but their contribution to the energy mix remains limited.<sup>42</sup> With some of the highest solar irradiation in the world (estimated technical potential up to 15 GW of solar power and 1.5 GW of wind), Sudan is well endowed for renewables and clean energy. In practice, however, Sudan's electricity supply still relies on hydropower and fossil fuels. While Sudan's Renewable Energy Master Plan plans for 3,300 MW of solar and wind capacity by 2033, as of 2025, Sudan's total installed solar PV capacity is estimated at 190 MW, with almost no change since 2022.<sup>43</sup> While this is an official estimate likely based on reporting from government entities or extrapolations by the authors of the report, the number has likely increased significantly since the start of the war in 2023.<sup>44</sup> Sudan's first utility-scale solar plant in Al Fashir came online in 2020, providing electricity in a region previously served by stand-alone diesel generators.<sup>45</sup> On the other hand, wind power is virtually non-existent; only a single pilot demonstration turbine project was initially scheduled to start construction in 2020 and begin commercial operation by 2024. Due the

current conflict, operational plans are likely to have been pushed back.

That said, the government has ambitious plans on paper to scale up renewables. Policy documents and targets envision a dramatic increase in installed solar and wind capacity after 2030 compared to today's levels, specifically 2,190 MW of solar PV and 1,550 MW of wind.<sup>46</sup> Several large projects were announced by the previous government. These included plans for a 100 MW solar plant in Dongola and a 50 MW wind farm in Red Sea state, and feasibility studies for wind farms (300 MW total) and solar PV projects (20 MW total) were completed in 2016.<sup>47</sup> In addition, the previous government also planned to provide 2.5 million stand-alone solar home systems by 2023 in areas with limited access to the national grid.<sup>48</sup> However, most of these projects have struggled to secure financing and have not materialized. In practice, growth has come chiefly from small-scale and off-grid applications rather than utility-scale projects. Electricity access in Sudan is around 45 – 55%, mostly concentrated in urban areas. This means that the off-grid solar segment – including solar home systems and solar water pumps – has been a key early market for renewables in Sudan, especially in remote and rural communities in areas far from the national grid.<sup>49</sup>

## 2.6. Solar energy in Sudan pre-conflict

There are clear structural disparities that shape Sudan's energy landscape. Data from the Sudan Labor Market Panel Survey (SLMPS), the first round of which was conducted in June 2022,<sup>50</sup> reveals a dual reality: while public electricity remains the dominant source of lighting, a significant portion of the population still lacks access to any formal energy source. At the household level, there are persistent gaps in electrification. Regional heatmaps and bar charts illustrate how the

<sup>40</sup> Nagy, A et al. 2021. Sudan: A closer look at the Investment Act 2021. IFIR. Available on: <https://www.ifir.com/article/2a63733ixysbvcl-r19i2i/sudan-a-closer-look-at-the-investment-act-of-2021>; The Act was published in Sudan Gazette on 12 May 2021 number 1914, Available on: <https://moj.gov.sd/files/index/28>

<sup>41</sup> UNDP. 2020b. Sudan's first 'Solar lab' launches to provide quality-assured solar technology. Available on: <https://www.undp.org/ar-ab-states/press-releases/sudans-first-solar-lab-launches-provide-quality-assured-solar-technology>

<sup>42</sup> UNDP. 2020.

<sup>43</sup> Eni. 2025. World Energy Reviews 2025: Renewables. Available on: <https://www.eni.com/content/dam/enicom/documents/eng/visi-one/wer/2025/WER-2025-Renewables.pdf>

<sup>44</sup> In 2021, a Reuters article cited a source as claiming \$500 million had been invested in Sudan's solar sector with an estimated output of 500 MW. This has not been verified by any other source. See Reuters. 2020. Sudanese bank launches first green sukuk for renewable energy. Available on: <https://www.reuters.com/article/business/finance/sudanese-bank-launches-first-green-sukuk-for-renewable-energy-idUSL5N2N1R6/>

<sup>45</sup> Terra Energy. 2023. Utility-scale solar in Sudan – case study of Al-Fashir Plan. Terra Energy Ltd. Kigali, Rwanda. Available on: <https://terraenergi.co/wp-content/uploads/2023/03/Utility-Scale-Solar-in-Sudan.pdf>

<sup>46</sup> Al-Rikabi, I. et al. 2024. Renewable energy in Sudan: Current status and future prospects. Engineering Reports 7(1): e13116.

<sup>47</sup> UNDP. 2020.

<sup>48</sup> World Bank. 2019. From Subsidy to Sustainability: Diagnostic Review of Sudan's Electricity Sector. Available on: <https://documents1.worldbank.org/curated/en/486961588608080192/pdf/From-Subsidy-to-Sustainability-Diagnostic-Review-of-Sudan-Electricity-Sector.pdf>

<sup>49</sup> Salah, M. and Bashier, R. 2023. (Un)Just transition in power generation: neoliberal reforms and climate crisis in Sudan. Review of African Political Economy 50(177-178): 402-420.

<sup>50</sup> Krafft, C., Assaad, R. and Cheung, R. 2024. Introducing the Sudan Labor Market Panel Survey 2022. Demographic Research 51: 81-106.



central, eastern and northern regions benefit from higher grid access and moderate solar uptake, whereas rural areas, especially in Darfur and Kordofan, rely more heavily on traditional fuels such as firewood or candles.

For firms, the dominance of private generators over both grid electricity and solar reflects widespread energy insecurity and self-reliance, as enterprises compensate for unreliable infrastructure. However, the data also expose the limited penetration of solar in commercial contexts. Only a handful of household businesses report using it, with nearly all concentrated in a single region. Taken together, these findings reveal that, in the period before the conflict, Sudan's use of solar energy was uneven and segmented.

Figure 8 shows the distribution of energy sources used by households. Households using the national grid are mostly concentrated in the central, eastern and northern regions (Figure 9). A large number of households report having no lighting at all. Very small numbers of households rely on gasoline bulbs, candles, generators, gas, straw, "Ratina," or biogas, each with negligible counts.

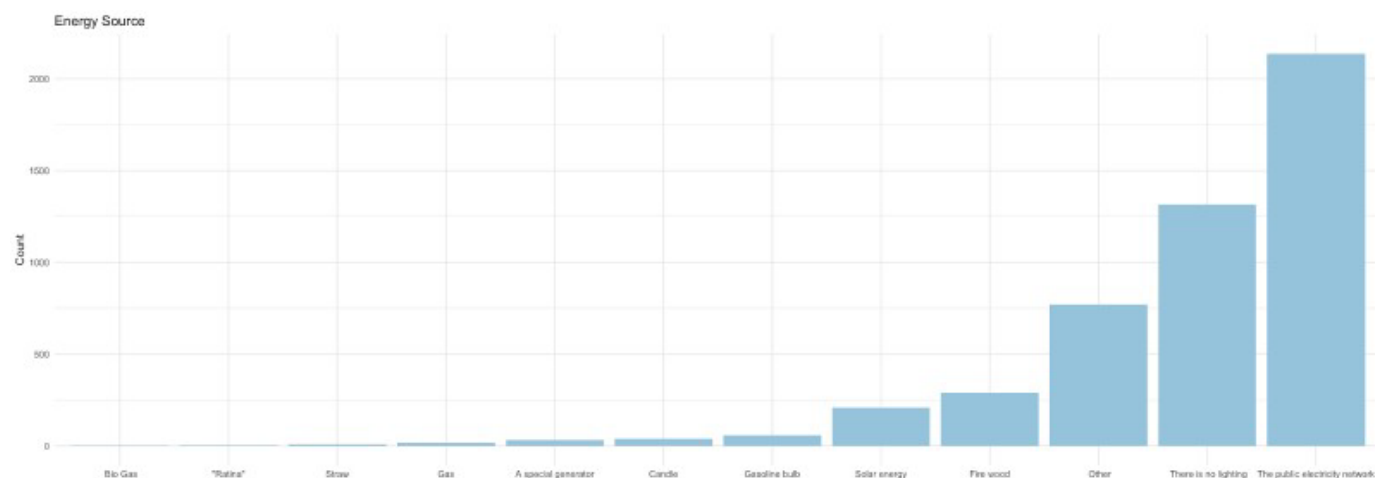
This heatmap in Figure 9 shows the distribution of various energy sources across different regions. The x-axis represents the regions (Khartoum, Darfur, Kordofan, Central, North, East), while the y-axis shows various energy sources: solar energy, candles, firewood, gasoline bulbs, and the national grid. The color scale on the right indicates the frequency of energy source

usage, with darker colors representing higher usage. Figure 9 shows that use of grid electricity is most common in Khartoum, while other regions, especially Darfur and Kordofan, rely more on traditional energy sources like firewood, candles, and straw.

Figure 10 shows the regions with the highest adoption of solar energy in 2022 at the household level in Sudan. The x-axis represents the regions (North, Central, East, Darfur, Kordofan, Khartoum) and the y-axis representing the adoption rate (in percentages). There are clear regional disparities: Khartoum leads with the highest solar adoption rate among households (just above 7%), followed by Kordofan (around 6%), Darfur (close to 5%), and then East and Central with notably lower rates (around 3%). The data suggest that solar adoption is concentrated in more urbanized or developed regions (such as Khartoum), but also shows strong uptake in Kordofan and Darfur, which may reflect energy needs in areas with limited grid access. In contrast, the Central and Eastern regions lag, potentially due to either stronger grid coverage reducing the incentive for solar or lower purchasing power relative to Khartoum.

This bar chart in Figure 11 shows the distribution of energy sources used by businesses. The x-axis shows the ownership rate (percentage of businesses reporting each source), while the y-axis lists the types of energy. The data shows that the most common energy source used by businesses is the private generator. The second most common source of electricity for businesses is the national grid. Just over 0.5% of businesses reported using solar energy as a source of electricity.

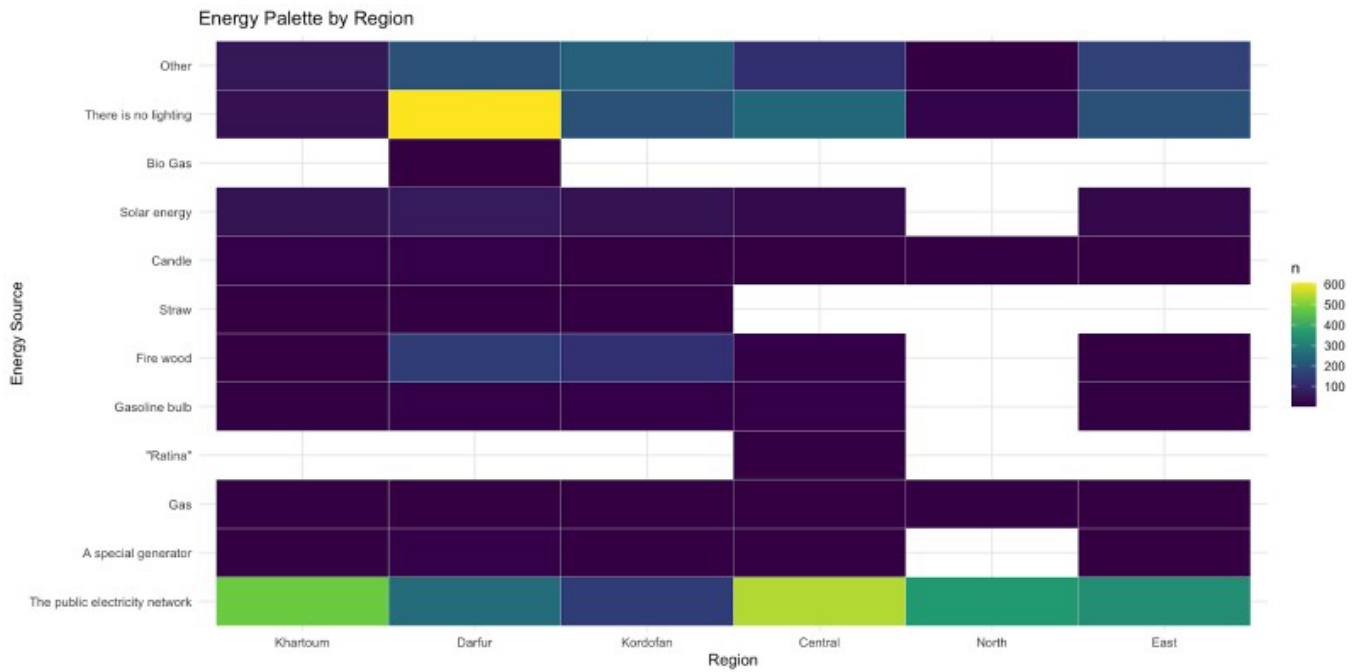
*Figure 8. Number of sampled households using different types of energy*



Source: SLMPs

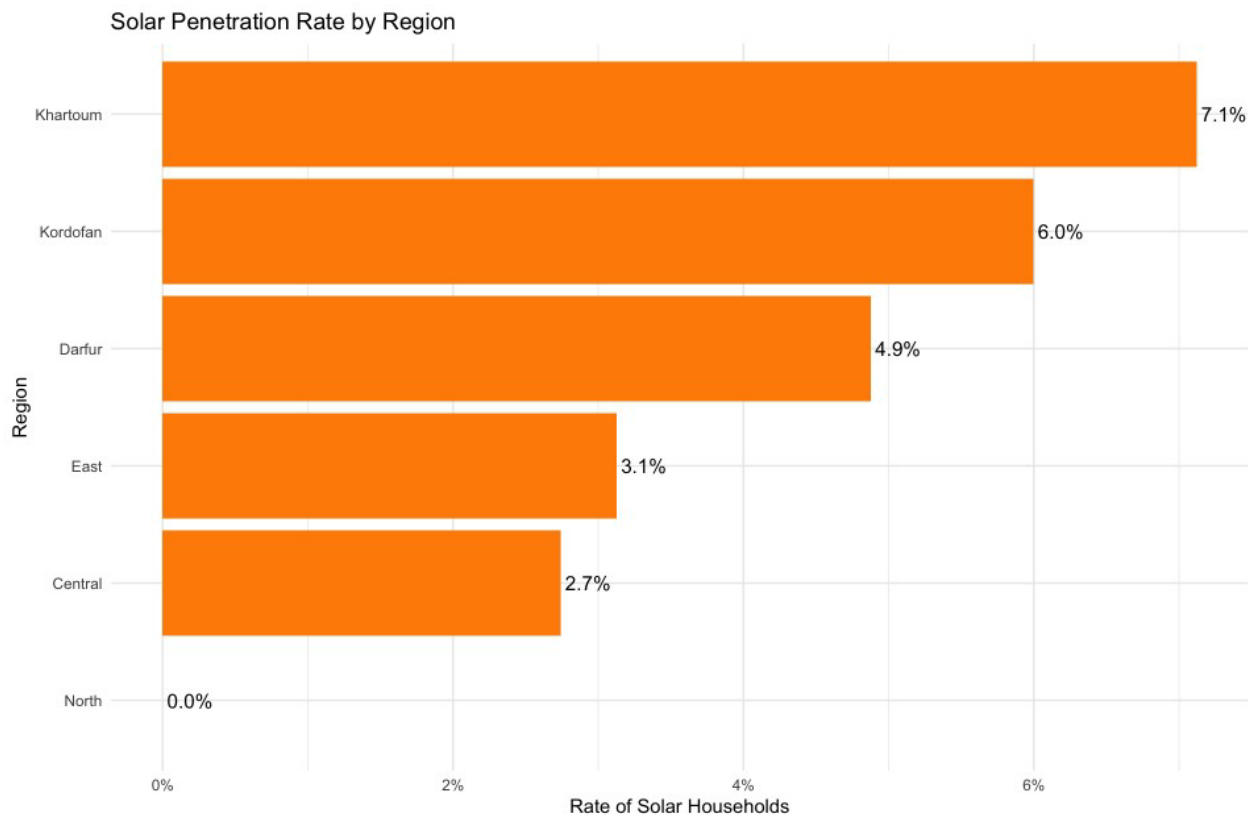


Figure 9. Use of different energy types by region



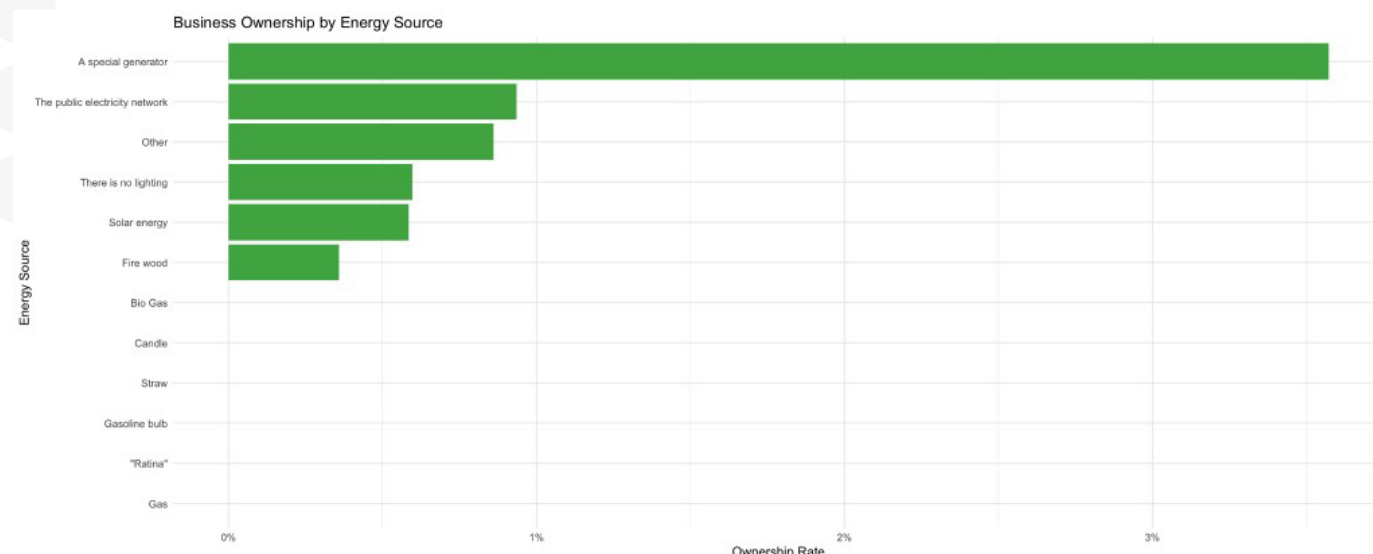
Source: SLMPS

Figure 10. Proportion of households that use solar energy by region



Source: SLMPS



*Figure 11. Distribution of energy sources used by businesses*

Source: SLMPS

## 2.7. Sudan's solar PV imports

Trade data spanning 2018 to 2025 illustrates how international solar trade dynamics intersect with Sudan's domestic (involuntary) energy transition. While global and regional markets for solar equipment have expanded rapidly, Sudan's trajectory was modest before the conflict and remains uneven, revealing both opportunities and structural constraints. The data highlight the growing dominance of China in renewable technology exports and the unequal diffusion of solar capacity across developing regions.

Figure 12 compares Sudan's solar PV imports to the Sub-Saharan African and global average over the same period and Figure 13 shows Sudan's cumulative imports of solar PV from China. The volatility in imports in Sudan is due to policy changes and conflict-driven demand. The removal of fossil fuel subsidies in September 2020 and the unification of the exchange rate at the prevailing market rate in February 2021 made solar PV much more competitive against diesel generators.<sup>51</sup> This is shown by the increase in imports in 2021. The second period of increase in imports in 2024 is due to increased demand for solar PV after the start of the conflict. Due to the destruction of the electricity infrastructure demand for solar PV increased, even for households and businesses previously connected to the grid. This demand likely took time to materialize (April 2023 to January 2024) because of the instability of supply chains in the months directly after the start of the conflict.

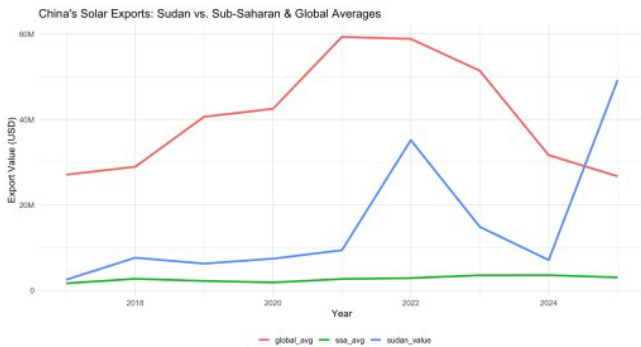
<sup>51</sup> IMF. 2021. Second Review Under the Staff-Monitored Program and Request for Extension – Staff Report; and Statement by the Executive Director for Sudan. IMF Country Report No. 21/143. Washington, D.C.: IMF.

Figure 14 shows monthly solar capacity imports in Sudan over the period 2017 to 2025. Similar to the trend observed in Figure 8, the peaks are associated with increases in demand due to policy changes and the recent conflict. Figure 15 shows the evolution of prices for solar PV imports into Sudan. The price in US\$ per W shows a consistent decline over time, decreasing from US\$ 0.38 per W in early 2017 to between US\$ 0.05 to 0.10 per W in mid-2025, a 73 – 85% decrease over an 8-year period. Figure 16 shows the composition of components in solar PV imports in Sudan. Almost all imports of solar PV in Sudan are panels, with a very small proportion of cells imported in 2022, 2023 and 2025. Figure 17 shows value in US\$ of solar PV imports in Sudan and the cumulative capacity of imports over the period 2017 to 2025. The reduction in the cost of solar PV in US\$ per W can be seen by the changes in cumulative capacity corresponding to the peaks in the value of the solar PV imported. For example, the peak in early 2022 of US\$ 15 million per month corresponds to a modest increase in cumulative imported capacity, whereas a peak of similar value in early 2025 corresponds to almost a 100 MW increase in cumulative solar capacity.

There does not seem to be an obvious trend in the imports of solar PV components into Sudan, with both monthly and annual data showing random fluctuations. This is despite the fact that some interviewees operating in the solar PV sector mentioned that imports tend to increase seasonally to satisfy demand in the agricultural sector. Demand in the sector tends to follow the harvest season, after which farmers use solar-powered pumps for irrigation.

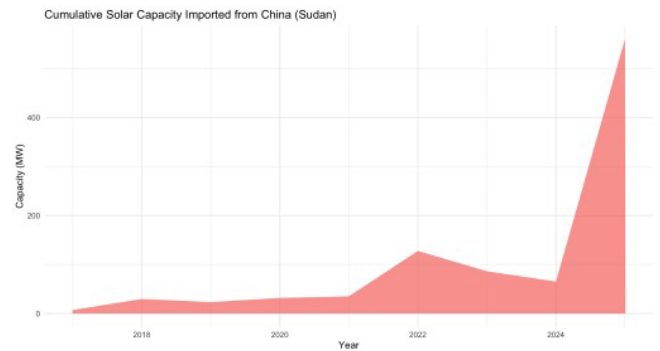


**Figure 12. Solar PV exports to Sudan (blue line), Sub-Saharan Africa average (green line) and global average (red line)**



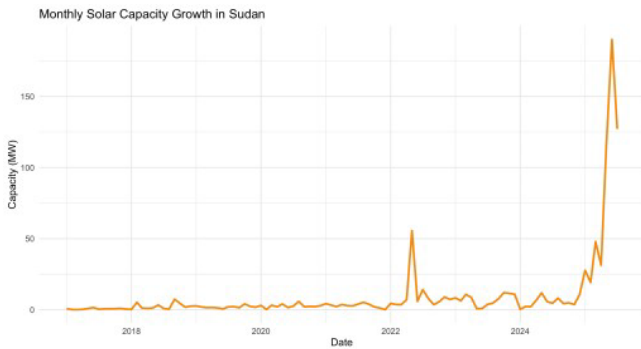
Source: Ember Energy

**Figure 13. Solar PV imports in Sudan over time for the period 2017 to 2025**



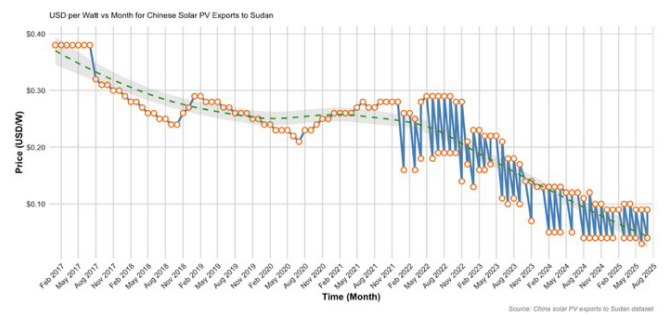
Source: Ember Energy

**Figure 14. Monthly solar capacity imports in Sudan**



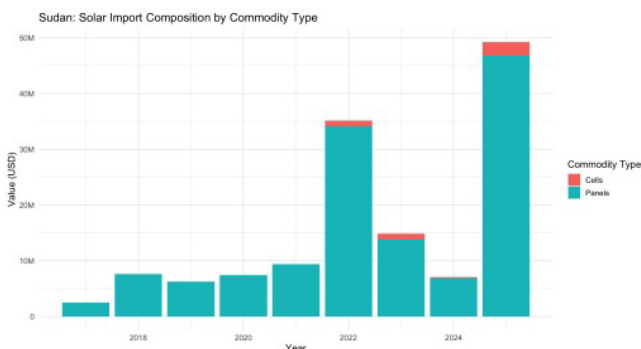
Source: Ember Energy

**Figure 15. The evolution of prices of solar PV imports in Sudan over time for the period 2017 to 2025**



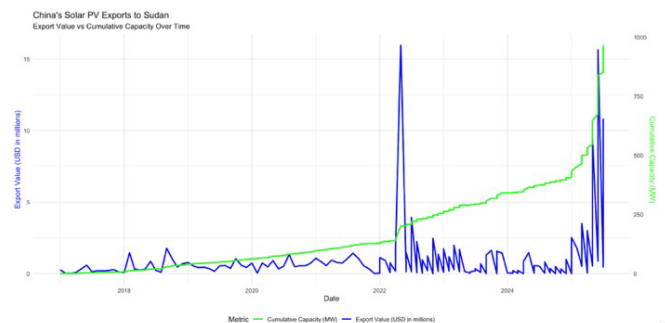
Source: Ember Energy

**Figure 16. Annual imports of solar PV components by type of component**



Source: Ember Energy

**Figure 17. Total value of solar PV imports and cumulative capacity in Sudan**



Source: Ember Energy



### 3. The impact of the war on MSMEs

The ongoing conflict in Sudan has resulted in a multifaceted crisis for Micro, Small, and Medium Enterprises (MSMEs). The analysis in this section draws on qualitative data that was collected as part of an ERF project on the role of MSMEs in the energy transition in Sudan. The data was collected from 8 states across Sudan between October and November 2023.<sup>52</sup> It also draws on a recent policy note published by IFPRI on the impact of the conflict on MSMEs based on an enterprise survey conducted in 2024.<sup>53</sup> The focus group discussions included participants who owned or managed MSMEs across different sectors in the different states in the study. All the information derived in the section is from this dataset.

The policy note from IFPRI examines the impact of the ongoing conflict on Sudan's MSMEs. Based on a 2024 survey of over 1,400 enterprise owners, the note highlights how businesses in Sudan navigate instability, inflation and supply chain disruptions. The findings show that the conflict had different effects on firms based on their size, with smaller firms often displaying unique forms of resilience compared to larger ones. Micro (< 5 employees) and small (5 – 9 employees) enterprises demonstrated greater resilience in sales during the conflict. The majority of Sudan's MSMEs – based on the sampling strategy of the data collected by IFPRI – fall into the micro category. And while women-owned micro-enterprises traditionally focused on trade and services (less labor intensive), the conflict has pushed an increasing number into agricultural activities. Smaller enterprises rely on informal community and family networks for financial and logistical support. To cope, in this category, some women entrepreneurs have transitioned to flexible, home-based models and digital platforms to maintain operations despite mobility constraints – although the number of women transitioning to digital platforms is probably limited to specific areas with ICT network coverage.

Medium-sized enterprises faced sharper declines in sales compared to smaller firms. In this category, male ownership is more dominant compared to micro and small firms: 80.6% of medium-sized firms in the sample are male-owned. This enterprise category is much more sensitive and vulnerable to the suspension of formal loan programs, disruption to banking operations and bank interest rates.

<sup>52</sup> Ali et al. 2024.

<sup>53</sup> Kirui, O. et al. 2024. Supporting Sudan's Entrepreneurs in Crisis: Policy Insights from Micro, Small and Medium Enterprises. Sudan Strategy Support Program Policy Note 9. IFPRI.

Regardless of size, most MSMEs in Sudan at the end of 2024 were operating at less than half their capacity due to asset losses, a reduction in labor supply and increases in logistic costs. After the conflict the sales gap between male and female owned enterprises decreased. Before the conflict, female-owned enterprises earned 43% less than male-owned ones. During the conflict, the gap narrowed to 29%, likely due to shifting gender-specific vulnerabilities, conflict-induced uncertainties and the impact of the conflict on male-dominated medium-sized enterprises. Moreover, women face steeper hurdles in accessing finance, and are often required to provide more collateral and documentation than men. This often forces women – who are more likely to own micro and small enterprises – to remain reliant on community support. While this support has been an important driver of the ability of small women-owned enterprises to adapt to shifting realities during conflict, it cannot provide the capital necessary for scaling.

In that respect, IFPRI's policy note highlights several interventions that could support entrepreneurs operating during the conflict. First, gender-sensitive microcredit, interest-free loans and support for community-based savings could enhance women's access to capital. Second, infrastructure support – storage and logistical support for agrifood MSMEs – and digital tools – providing literacy support in mobile banking and other platforms – could help MSMEs overcome mobility issues. Finally, support networks, such as mentorship and peer networks, could help owners of MSMEs navigate conflict-specific risks and manage business operations.

#### 3.1. Energy access and costs

Access to reliable and affordable energy emerged as a primary bottleneck. Lack of access has led to widespread disruptions of economic activity and exposed significant regional disparities. MSMEs contend with pervasive power outages exacerbated by the damage to energy infrastructure. Power outages often last days or even months. A critical structural inequality is evident in grid coverage:

- In Kassala, communities experienced daily power cuts, impacting agriculture and supporting sectors.
- The Northern State experienced frequent power outages, with some areas having no access to the grid.
- In White Nile state, particularly in its agricultural regions, there were areas with no electricity, forcing a complete reliance on generators.
- In contrast, in Port Sudan (Red Sea State), electricity in the winter is generally stable but issues arose in summer.
- The Blue Nile State, particularly Agadi locality, is



not covered by the national electric grid, necessitating alternative energy sources. This lack of basic infrastructure in rural agricultural areas inherently disadvantages farmers, limiting their productivity.

Compounding grid failures is the scarcity of diesel and gasoline. In most states, increases in the cost of diesel for generators eats into firm profits and significant challenges accessing fuel. In White Nile state, farmers faced significant challenges, some unable to water crops for 12 days. This widespread dependence on costly, often smuggled fuel creates a volatile operational environment and significantly increases production costs.

The conflict has reduced production capacity and output, with some enterprises forced to cease operations. Some Gedarif farmers reported output dropping by 50% due to unstable electricity. In Kassala, farmers may leave crops unharvested due to prohibitive costs. Unstable electricity and voltage fluctuations also damage sensitive equipment and reduce product quality. Businesses struggled to preserve temperature-sensitive products during blackouts. Reliance on manual labor increased costs and slowed down production. Agricultural activity faced delayed planting, reduced cultivation and poor yields.

The conflict broke down supply and distribution networks across Kassala, Northern State, Red Sea, White Nile, Blue Nile, Gedarif, and Sennar. Import bottlenecks meant scarce and expensive equipment like solar panels and batteries. Raw materials and goods were hard to access, especially from Khartoum. Soap factories in Northern State struggled to get inputs, and pharmacies in River Nile faced shortages. Increased transport costs due to unsafe roads and higher fuel prices worsened conditions. Businesses also faced risks of robbery, damaged goods, and falling crop prices due to halted exports.

The conflict undermined the financial viability of many MSMEs and worker well-being. Financial constraints prevented businesses from hiring or retaining staff, often leading to layoffs. Manual labor raised costs further. Some individuals faced severe personal financial losses due to failed ventures. Broader instability deterred investment in new energy solutions. Increased taxation and customs fees for imported equipment worsened financial strain on MSMEs. Psychological stress reduced motivation and risk appetite, while disrupted communication hindered coordination. This was particularly acute for firms operating in the agricultural sector.

### *3.2. Adaptive strategies and infrastructure gaps*

MSMEs shifted towards alternative energy, especially solar power, due to scarce and costly fuels. Businesses also reduced operating hours, postponed work, or relied on manual labor. Farmers reduced cultivated areas or operated seasonally. Some made risky direct electricity connections. Others increased prices to cover costs, though this reduced customer demand. Despite a general shift towards solar, there are some significant challenges to widespread adoption:

- **Energy infrastructure:** The national electricity grid became highly unstable. Frequent and prolonged outages became the norm. The cost of delivering electricity to distant projects became prohibitively high. While generators were a common backup, their operation became extremely expensive due to fuel costs and scarcity, and spare parts were often unavailable. Although solar energy was generally recognized as a beneficial, stable and cost-saving alternative, initial installation costs are untenable for most MSMEs and farmers across the country. This was the most significant and most cited barrier. Furthermore, solar systems may not adequately power all heavy machinery or support 24-hour operations without expensive batteries, a concern for industrial activities in Northern State and River Nile. This was especially the case for the mining sector. Space for installation is also a concern in the Northern State. MSMEs operating in urban areas struggled to find space for installing solar panels.
- **Financial infrastructure:** MSMEs faced severe financial constraints and a lack of liquidity. It became difficult for most firms to afford necessary inputs, energy or invest in new technologies like solar power. The conflict led to the closure of banks or a reduction in their operations, including loans and funding programs. Existing loan options were available but with high interest rates (20 to 35%) or short repayment periods (6 to 8 months). Increased operating costs for fuel and inputs ate away at a significant portion of potential profits. This left little room for investment. Specific calls for the government to establish financial portfolios for renewable energy and exempt solar panels from customs fees are widespread in Northern State, Blue Nile, River Nile and Gedarif.
- **Awareness and technical capacity:** There is a general lack of awareness and knowledge about renewable energy technologies among farmers and small business owners in Kassala, Northern State, Gedarif, White Nile and Blue Nile. Many are hesitant towards adopting new, untested technologies. Many claimed that they preferred traditional meth-



ods and feared taking risks or potential losses from misuse. This is particularly evident in Kassala, Northern State, Gedarif, Blue Nile and White Nile. A scarcity of qualified technicians and engineers for proper installation, maintenance and troubleshooting further discouraged adoption in Kassala, Northern State, Gedarif, Red Sea and Blue Nile. There were also widespread concerns in Kassala, Northern State and Gedarif about the quality of imported solar panels and equipment. Many were wary of fake or low-quality products that could lead to system failure and financial loss. The absence of reliable warranties or guarantees from suppliers made farmers more skeptical.

- Government policy and support gaps: There is a perceived lack of government interest, support and clear policies to facilitate the adoption of decentralised, off-grid clean energy, including exemption from customs duties for solar. Some MSMEs claimed that government entities, like the SEDC, may even actively resist the adoption of alternative energy due to fears of losing income. MSMEs emphasized the need for the government to implement clear policies to increase adoption of renewable energy across the country. Establishing a regulatory framework that allows selling excess energy back to the national grid was also suggested in River Nile to incentivize adoption. Furthermore, security guarantees were suggested as a potential solution needed to protect investments in expensive renewable energy systems from theft or damage, especially in conflict-affected regions.

Despite clear benefits, many MSMEs were hesitant to adopt solar energy due to high upfront costs, past poor experiences with installations, lack of guarantees and limited awareness. This reluctance constrains broader renewable energy adoption. Solar energy offers several benefits to MSMEs affected by the conflict:

- Operational continuity: Solar energy offers a stable and continuous power supply. This is crucial for businesses frequently interrupted by blackouts or fuel scarcity. This stability enables sustained production and reduced losses.
- Reduced operational costs: While the initial investment is high, solar energy is expected to significantly reduce long-term operational costs by eliminating expenses for fuel, generator maintenance and frequent electricity purchases.
- Increasing productivity and employment: With stable energy, businesses can increase production volume, cultivate more land, and potentially re-hire or expand their workforce.
- Environmental and psychological benefits: Renewable energy is lauded as clean and environmentally friendly, which is especially relevant for MSMEs

operating in states with high use of traditional fuels. It also provides assurance and reduces stress about power cuts or fuel scarcity.

### *3.3. The role of MSMEs in Sudan's economy*

Sudan's economic structure, like that of many fragile states, is overwhelmingly reliant on MSMEs. Formal statistics are scarce and often unreliable or incomplete, but estimates consistently show that MSMEs constitute over 90% of all non-agricultural firms and account for the vast majority of informal employment. Within this, the informal MSME sector is pivotal to the economy's resilience to political and economic shocks, encompassing street vendors, artisans, small repair shops and local trading companies. These enterprises are the primary source of income generation for most Sudanese households.

The formality gap is a key feature: the majority of businesses operate outside formal registration, regulatory compliance and the traditional banking sector. This informality, however, is paradoxically a source of their strength in a fragile state. MSMEs in Sudan seem to have developed sophisticated, localized coping mechanisms to navigate political instability, currency fluctuations and active conflict. When supply chains break down at the national level, local traders quickly reroute imports through complex, informal cross-border networks. When banking systems freeze, they rely on traditional systems of money transfer, informal currency traders and trust-based credit relationships within their communities to maintain cash flow. This ability to operate effectively where formal institutions fail makes them uniquely suited for last-mile service delivery of energy.

In the context of decentralized renewable energy systems, MSME advantages manifest in several ways:

- Trust and customer acquisition: Large, impersonal companies (both Sudanese and non-Sudanese) struggle to build the necessary trust with remote, less bankable consumers. Local MSMEs tend to be integrated into the social fabric. They tend to know their customers' creditworthiness based on long-standing relationships, and can secure commitments where outsiders cannot.
- After-sales service and maintenance: decentralized renewable energy technologies require ongoing maintenance and technical support. Relying on centralized maintenance teams in a conflict environment is unfeasible. Local MSMEs, such as mobile phone repair shops, bicycle mechanics or electrical technicians, can be trained and equipped to serve as accessible local maintenance hubs to reduce service costs and response times.



- **Local resource mobilization:** MSMEs are experts in managing local currency risk and finding local labor and resources for installation. They can leverage existing non-energy supply chains (for example, transport networks used for food or agricultural goods) to distribute solar system equipment. This is both easier and cheaper than establishing new, dedicated distribution channels.

Therefore, a Mission 300 research program must view Sudanese MSMEs as central to the sustainability and success of decentralized energy solutions. Mission 300 can simultaneously achieve three strategic goals by technical and financial assistance and specific regulatory reforms toward MSME formalization and capacity building:

- **Electrification:** Deploy decentralized renewable energy solutions at scale by overcoming the last-mile delivery hurdle.
- **Increase in economic activity:** Deploying financial and technical support towards MSMEs would reduce reliance on aid and boost local employment and diversify local economies.
- **Conflict mitigation:** Economic and income opportunities and reliable access to essential services contribute to social stability and cohesion.

The subsequent sections of this report will therefore focus on the methodologies required to precisely map this MSME capacity, design financial products that can flow through this informal yet resilient ecosystem, and ensure that the delivered energy powers productive economic activities.

## 4. Conclusion

The state of the Sudanese energy landscape confirms a critical point for the Mission 300 initiative: conventional, large-scale, utility-centric electrification models may not be viable in regions characterized by high, persistent fragility. Sudan's political and economic volatility requires a decentralized, bottom-up approach that, in the short-term, treats energy access as a local market development and resilience-building opportunity, and, in the long-term, as an infrastructure challenge. MSMEs emerge as the only credible, resilient last-mile delivery mechanism capable of achieving Mission 300's mandate in such challenging environments.

Achieving Mission 300's goal in Sudan and similar fragile states requires a re-appraisal of what constitutes a sustainable intervention. Success should not be measured in megawatts, but in the resilience of the local MSME delivery channel, the viability of the

underlying Productive Use of Energy and the efficacy of the de-risking capital structure. The MSME is the engine of local economy, and by empowering this sector as the primary agent of decentralized electrification, Mission 300 transforms a humanitarian problem into a sustainable commercial opportunity. The framework and recommendations presented here offer a clear pathway for evidence-based intervention to position Sudan as a critical pilot study for connecting the world's most vulnerable populations to clean, reliable power. One lesson from Sudan is that MSMEs (electronic repair shops, hardware stores, local traders) can be a layer of resilience. They are intrinsically tied to informal credit networks and possess high social capital and local knowledge required for last-mile delivery. They are uniquely positioned to manage the high transaction costs and extreme operational risks associated with volatile payment environments, making them far more effective than centralized entities or international NGOs in maintaining service continuity. The MSME could be the mission's partner.

Financial sustainability is a function of a customer's Capacity-to-pay, which is typically insufficient for asset financing in low-income, fragile contexts. The only mechanism to increase capacity-to-pay and ensure loan repayment is through expanding Productive Use of Energy (PUE). Projects that focus solely on lighting and phone charging (Tier 1 and 2) are high-risk. Mission 300 should prioritize PUE, bundling higher-efficiency, income-generating appliances (for example, solar water pumps, milling units) with decentralized renewable energy systems. This approach links the energy system directly to local economic activity that generates revenue for repayment.

Sudan, despite its challenges, offers a unique, real-world laboratory for developing solutions scalable to other FCS, such as South Sudan, Yemen or the DRC. Future research efforts could build on the foundations and evidence developed through piloting decentralized solutions in Sudan. Moreover, this pilot could benefit from existing models of energy provision in fragile contexts.<sup>54</sup>

<sup>54</sup> See, for example, Lebanon's dynamic off-grid solar market (Dagher, L. 2025. From Crisis to Opportunity: Advancing Solar Energy in Lebanon Through Effective Policymaking. Arab Reform Initiative. Available on: <https://www.arab-reform.net/publication/from-crisis-to-opportunity-advancing-solar-energy-in-lebanon-through-effective-policymaking/>) and Yemen's solar sector (UNDP. 2025. Empowering Yemeni communities through solar energy. Available on: <http://undp.org/arab-states/stories/empowering-yemeni-communities-through-solar-energy>).





**ERF at a Glance:** *The Economic Research Forum (ERF) is a regional network dedicated to promoting high-quality economic research for sustainable development in the Arab countries, Iran and Turkey. Established in 1993, ERF's core objectives are to build a strong research capacity in the region; to encourage the production of independent, high-quality research; and to disseminate research output to a wide and diverse audience. To achieve these objectives, ERF's portfolio of activities includes managing carefully selected regional research initiatives; providing training and mentoring to junior researchers; and disseminating the research findings through seminars, conferences and a variety of publications. The network is headquartered in Egypt but its affiliates come primarily from different countries in the region.*

#### Contact Information

##### ERF Office

**Address:** 21 Al-Sad Al-Aaly St. Dokki, Giza, Egypt

PO Box 12311

**Tel:** +202 333 18 600 - 603

**Fax:** +202 333 18 604

**Email:** erf@erf.org.eg

**Website:** <http://www.erf.org.eg>

#### Follow us



[economic-research-forum](https://www.linkedin.com/company/economic-research-forum)



[ERFLatest](#)



[TheERFLatest](#)



[www.erf.org.eg](http://www.erf.org.eg)

