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Power and Poverty
How Financial Institutions Can Support Scalable Rural Electrification in Côte d'Ivoire

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TABLE OF CONTENTS

ABSTRACT

This thesis investigates the relationship between rural electrification and poverty reduction in Côte d'Ivoire, with specific focus on the role played by solar energy systems and funding arrangements.

A mixed-methods research design involving quantitative regression analysis and qualitative case studies of the Elokato-Bingerville micro-grid and the Boundiali Solar Power Station reveals how access to electricity can be a force for inclusive development. The findings indicate that while decentralized micro-grid models offer tailored solutions to off-grid communities, utility-scale solar projects can potentially backstop national infrastructure and mobilize capital of scale. However, financing concerns, long-term sustainability, and institutional capacity issues exist. The study presents several innovative policy recommendations and financial products, including results-based financing, private-community models, and blended finance models. Overall, the thesis emphasizes the need to pursue a context-appropriate hybrid approach to electrification that combines technical measures with social equity, climate goals, and financial sustainability to provide universal access to energy in Côte d'Ivoire by 2030.

INTRODUCTION

Africa is often referred to as the “continent of the future”. It is a young and dynamic region rich in resources, entrepreneurial potential, and opportunities for sustainable development. Yet, for this potential to be fully realized, one fundamental condition must be met: universal access to reliable and affordable energy. Energy is not just a utility; it is a driver of inclusive, socio-economic development. Without it, entire communities remain locked out of progress, because better healthcare, quality education, and meaningful job creation cannot be achieved.

In Sub-Saharan Africa, and particularly in countries like Côte d'Ivoire, access to reliable energy remains one of the most pressing challenges for rural communities. While urban electrification has advanced, rural communities still face significant barriers to energy access, often relying on expensive or polluting alternatives. Despite significant improvements, rural electrification rates lag behind national goals, thus limiting economic development and social inclusion. In this context, distributed solar energy systems - especially those built on micro-grid models- have emerged as promising solutions, since they offer clean and decentralized energy that can be rapidly deployed, scaled, and tailored to local needs.

At the same time, Africa presents a unique opportunity not only for energy innovation but also for the development of sustainable financial ecosystems. The intersection between finance and energy access is increasingly important: traditional funding mechanisms often fall short when it comes to reaching unserved population.

Banks and financial institutions can then play a transformative role by developing tailored instruments based on the needs and possibilities of local communities – such as micro-financing, blended finance, or risk-sharing models. In doing so, they can open new markets, foster financial inclusion, and implement private sector participation in the energy transition.

However, this opportunity brings with it a critical sustainability challenge. If we want to keep pace with the goals of the 2030 Agenda of the United Nations, it is not enough to deploy solar panels or fund pilot projects. The solutions must be economically viable, socially inclusive, and environmentally sustainable over the long term. This raises important questions: how can financial systems be designed to serve both the needs of investors and the realities of rural communities? What policy frameworks are necessary to ensure long-term impact? How can the concept of "bankability" be redefined to unlock scalable energy investments in Côte d'Ivoire?

This thesis addresses these questions with a special focus on the case of Côte d'Ivoire. It will pay special attention to how banks and financial institutions can support the scalable deployment of solar micro-grids for rural electrification in Côte d'Ivoire. The work will be articulated in four chapters: in the first one, a literature review exploring the already existing material on the topic will be presented to introduce the subject matter of interest. The second chapter will be dedicated to a description of the research design techniques used to investigate and answer the research question. The third one is instead more practical and concrete, exploring the quantitative part concerning the relationship between rural electrification and reduction of poverty, and the qualitative part concerning two real projects put in practice on place. Chapter four, the last one, based on all the previous analyses and observations, aims at highlighting some policy implications and give some recommendations to help the country in its pursuit of electrification. The conclusion will then sum-up all the material and, finally, tries to answer the research question.

CHAPTER 1: LITERATURE REVIEW

This chapter reviews the existing literature on rural electrification, access to energy, distributed solar energy systems and the financial and policy mechanisms that support their deployment in Sub-Saharan Africa and in particular Côte d'Ivoire. The main purpose is to provide an overview of how energy access is linked to socio-economic development, to explore the potential of solar micro-grid systems in rural contexts and analyse the role of banks and financial institutions in implementing these solutions. It highlights both the opportunities and challenges presented in previous studies on the topics, thus paving the way for further discussion on the importance of our research. The academic literature on the electricity sector in Côte d'Ivoire is scarce, and the recent literature focuses on the more theoretical and financial aspects relating to the implementation of renewable energy and on electricity access for rural population.

1.1 Energy Access and Development in Africa

Energy access is widely recognized as a fundamental driver of socio-economic development. Africa will see its population double in thirty years, reaching almost 2.5 billion inhabitants by 2050, and 40% of them will be in rural areas (INED.fr)[1]. About 645 million Africans do not have access to electricity, and per capita energy consumption in sub-Saharan Africa is currently estimated at 181 kilowatts per year, the lowest of any continent. Energy sector impediments and electricity shortages are estimated to cost the African continent 2% to 4% of GDP annually[2], damaging economic growth, employment creation and investment. Nearly 600 000 Africans – mostly women and children – die annually due to indoor air pollution because of the use of fuel wood for cooking. Children suffer the lack of electricity since more than 90% of Africa's primary schools is not

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[1] INED – Institut national d'études démographiques. Population projections for Africa by 2050. https://www.ined.fr

[2] African Development Bank. (2022). Energy sector and its impact on African economies. https://www.afdb.org/en/news-and-events/press-releases/energy-access-africa-2030-key-development-17948

equipped with it, and lives are at risk in many African hospitals, as life-saving equipment are unused due to the lack of electricity (African Development Bank, 2022).

In Côte d'Ivoire, the Rural Electrification Program (PRONER) is committed to electrifying the whole country by the end of 2025[3]. The project has four components, among which we find power infrastructure and social connections, thus highlighting the urgent need for energy access to foster economic development and social inclusion (African Development Bank Group, 2021).

Scholars such as Cook (2012) and Barnes (2012) have put the accent on the multifaceted role[4] of energy access and rural electrification in the development of a country, arguing that electrification allows structural transformation in rural economies.

1.2 The Role of Solar Micro-Grids in Rural Electrification – Insights from Côte d'Ivoire

Micro-Grids (MGs) are localized energy systems, energy storage, energy control and conversion, energy monitoring and management, that can operate independently or in conjunction with the main electricity grid, which generates, distributes, and manages electricity for a specific area (a village, a community…). Micro-grids often integrate renewable energy sources (solar, wind, biomass…) with energy storage systems and sometimes backup diesel generators to ensure reliability. They are increasingly used in remote or underserved areas as a solution for rural electrification.

The installation of micro-grids has proved particularly successful in many African countries. In Kenya, for instance, the population without access to electricity was estimated to be about 33-35 million people out of a population of 38.5 million in 2010 and 43.13 million in 2012. The significant shortage of electricity supply in the rural areas of Kenya has brought about many micro-grid initiatives for off-grid rural communities.

[3] African Development Bank Group. (2021). Côte d'Ivoire: African Development Bank approves 50.46 million euros to electrify 1,200 localities. https://www.afdb.org/en/news-and-events/press-releases/cote-divoire-african-development-bank-approves-5046-million-euros-electrify-1200-localities-43936
[4] Cook, P. (2012). Infrastructure, rural electrification and development. Energy for Sustainable Development, 16(4), 573–579. https://doi.org/10.1016/j.esd.2012.08.003
Barnes, D. F. (2012). The challenge of rural electrification: Strategies for developing countries. Routledge.

Today, many rural communities in Kenya are powered by Photovoltaic (PV). In 2014, there were already 18 operational MGs with a total installed capacity of 19MW operated by the Kenyan utility (P. K. Ainah and K. A. Folly, 2015)[5].

Countries like Zambia and Tanzania also benefitted from the implementation of solar micro-grids projects. In Zambia, the rural electrification authority is in collaboration with the World Bank to provide electricity in rural areas, like in the Sinda village, where the micro-grid is made up of 0.78kW solar Direct-Current (DC) grid with the Lumeter metering system.

Tanzania is following the same path: to improve electricity access in rural areas, the government planned to implement a pilot micro-grids project in Lake Eyasi to provide social services using a solar powered system. Currently, 13 national utility micro-grids, mostly powered by diesel, serve remote communities across the country.

As far as Côte d'Ivoire is concerned, micro-grids are particularly well-suited for its remote communities due to several factors. First, geographical dispersion makes national grid expansion costly and inefficient in many rural areas – many rural communities are situated far away from the national grid. Second, the country enjoys abundant solar energy resources, offering excellent potential for off-grid solar systems. Third, the Ivorian Government is committed to achieving universal electricity access by 2025, with a focus on integrating renewable energy sources into the national energy mix.

Côte d'Ivoire has already launched different micro-grids pilot projects to enhance rural electrification. One of the most notable is ECLERE IVOIRE Project, financed by the European Union and implemented by Expertise France. The project involves the construction of 16 hybrid solar mini grids with a combined capacity of 792 kW, to serve remote communities. Beyond generating clean energy and empowering local communities, the project aims to reduce electricity consumption in public buildings and reinforcing the national policy for decentralized energy planning (Expertise France, 2022).

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[5] Ainah, P. K., & Folly, K. A. (2015). An overview of current microgrid policies, incentives and deployment in East Africa. IEEE PES PowerAfrica Conference. https://doi.org/10.1109/PowerAfrica.2015.7331996

Another notable initiative is a solar mini-grid feasibility study supported by the U.S. Trade and Development Agency (USTDA, 2019)[6] in collaboration with the Ivorian Ministry of Petroleum, Energy, and Renewable Energy. The study was launched in 2019 and aims to inspect the deployment of solar mini grids in up to 100 unelectrified communities, potentially benefitting nearly 200,000 people. These projects all demonstrate growing institutional support for micro-grid development and reflect the country's ambition to reach universal energy access through sustainable, decentralized systems.

1.3 Financing Models for Off-Grid Systems – and Ivory Coast's Financial Ecosystem

Financing models play a crucial role in determining whether rural population can access and sustain off-grid energy solutions.

In circumstances where the upfront investment is prohibitive and banking/financial services are limited, innovative financial mechanisms such as the Pay-As-You-Go (PAYGO) and blended finance have emerged as useful options to overcome investment barriers[7].

PAYGO is an innovative business model developed to address the energy access challenge and to provide electricity generated from renewable energy sources at affordable prices, with payments facilitated by the technologies available in the areas of interest (IRENA.org).

In Côte d'Ivoire, it has already been somehow implemented through different projects. For example, in 2020, a securitisation pilot project initiated by Crédit Agricole CIB and Grameen Crédit Agricole Foundation, has been launched. The company ZECI, created through a partnership between EDF and Zola Electric, offered a flexible financing approach to bring solar energy to off-grid rural households. Instead of requiring full

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[6] U.S. Trade and Development Agency. (2019). USTDA funds feasibility study to support rural electrification in Côte d'Ivoire. https://ustda.gov/ustda-funds-feasibility-study-to-support-rural-electrification-in-cote-divoire/

[7] International Renewable Energy Agency. (2018). Innovation landscape brief: Pay-as-you-go models. IRENA. https://www.irena.org/publications/2018/Nov/Pay-as-you-go-models
This report explores the PAYGO business model in energy access and how it can expand electricity access in off-grid regions.

upfront payment, the company allows customers to purchase solar kits through instalment plans that span up to three years. Payments are made via mobile money services, and the system is designed to be adaptable — users can adjust their payments based on their income flow[8]. Alongside product distribution, ZECI also manages system maintenance, ensuring both continued access and customer reliability in the long term (Crédit Agricole, 2020).

Another similar initiative was the one of Baobab+ that, in 2021, raised €4 million to expand its operations in Côte d'Ivoire and Senegal, aiming to equip one million households with solar and digital products within five years with the Pay-As-You-Go model[9]. In Senegal, Côte d'Ivoire, Mali and Madagascar, Baobab+ has been a pioneer in launching PAYG smartphone services and has also, to date, equipped more than 110,000 households with digital solutions (Symbiotics Group, 2022).

Blended finance, on the other hand, refers to a strategic tool to attract private investments into projects that are typically seen as too risky or not immediately profitable, especially in developing countries[10]. The idea behind it is to combine public or concessional funding with commercial capital, so that the public portion helps reduce the perceived risk for private investors. In the energy sector, and particularly in rural electrification, this approach has been used to make renewable energy projects more bankable and financially viable[11]. It can take the form of loan guarantees, first-loss protection, or co-investment structures, all designed to encourage private sector

[8] EDF & Zola Electric. (2020). ZECI - Off-grid solar in Côte d'Ivoire. https://www.zolaelectric.com/partnerships
ZECI, a joint venture between EDF and Zola Electric, developed PAYGO solar kits for rural homes with mobile money payments.
[9] Symbiotics Group. (2022). Baobab+ secures €4 million to expand solar access in West Africa. https://symbioticsgroup.com/baobab-raises-e4-million-to-expand-solar-access/
The article highlights Baobab+'s innovative financing strategy for solar and digital product access through PAYGO.
[10] Organisation for Economic Co-operation and Development (OECD). (2018). Making blended finance work for the Sustainable Development Goals. https://www.oecd.org/publications/making-blended-finance-work-for-the-sustainable-development-goals-9789264288768-en.htm
This comprehensive guide discusses how public and private finance can work together to fund sustainable projects
[11] United Nations Development Programme (UNDP). (2013). Derisking Renewable Energy Investment: A Framework to Support Policymakers in Selecting Public Instruments. https://www.undp.org/publications/derisking-renewable-energy-investment
This UNDP report presents a framework for using public finance to reduce private sector investment risks in clean energy.

participation in areas where investment would otherwise be unlikely. Many initiatives have also been undertaken from this perspective.

For instance, the IFC (International Finance Corporation) made huge investment in the social bond issued to support the Electricity for All Program (PEPT)—a government-led initiative aimed at connecting low-income households to the national grid. The bond, co-financed by the Emerging Africa Infrastructure Fund, is expected to support up to 800,000 new connections[12]. Structured through a securitization vehicle, the project demonstrates how capital markets and public-private collaboration can drive large-scale energy access. It also shows the potential of blended finance to unlock long-term, local currency funding for inclusive development (ifc.org).

1.4 Role of Banks and Financial Institutions – Focus on Ivorian Banks

As we already mentioned, accessing financing for renewable energy projects in developing countries like Côte d'Ivoire is usually perceived by investors as highly risky. Lack of adequate collateral and limited credit histories of borrowers hinders the investments. This makes financial institutions and banks reluctant to invest in off-grid renewable energy solutions.

The banking sector in Côte d'Ivoire comprises 28 banks, including major players like Société Générale Côte d'Ivoire, Atlantique Banque, Ecobank, and NSIA Banque. Banks are expanding their networks, especially in secondary cities outside Abidjan. The total number of bank branches increased from 281 in 2008 to 631 in 2016[13], thus reflecting efforts to improve financial accessibility (Privacy Shield Framework). However, despite these efforts, financial inclusion remains low, particularly in rural regions. According to the World Bank, only 41% of Ivorians had access to formal financial services in 2021[14],

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[12] International Finance Corporation (IFC). (2021). IFC supports Côte d'Ivoire's Electricity for All Program with social bond investment. https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=26863
The IFC press release outlines their co-investment in expanding electricity access through securitization and blended finance.

[13] Privacy Shield Framework. (2020). Côte d'Ivoire - Market Overview. https://privacyshield.gov/article?id=Cote-d-Ivoire-Market-Overview
This overview provides insights into Côte d'Ivoire's banking sector, infrastructure expansion, and investor environment.

[14] World Bank. (2021). The Global Findex Database 2021: Financial Inclusion, Digital Payments, and Resilience in the Age of COVID-19. https://globalfindex.worldbank.org/
This global database measures how people in Côte d'Ivoire and other countries access banking and digital finance.

and many remote communities remain excluded from traditional banking services. Mobile money has made progress in reaching these populations, but its use for long-term financing—such as for energy investments—remains limited.

Some local banks have begun to explore opportunities in renewable energy finance, though this engagement remains limited. The African Development Bank's Green Bank Initiative is an example of a project that aims to strengthen the capacity of local financial institutions in Côte d'Ivoire (but also in other African countries) to develop bankable green projects[15]. The model, which was presented in Egypt, aims to provide governments and financial institutions with technical assistance grants, fundraising support, and co-financing opportunities for green projects. In addition of that, this initiative will reinforce private sector actors, thus allowing them to have their own green projects financed in Africa (Trade.gov)[16]. Yet in practice, local banks remain cautious. Lending continues to focus on low-risk, short-term commercial loans, and very few banks are actively financing small-scale or off-grid renewable energy projects. A lack of specialized knowledge and risk assessment tools for clean energy initiatives still holds back broader engagement.

The Ivorian government is also working to strengthen its Fintech ecosystem through a new roadmap introduced for the 2022–2024 period[17]. Inspired by recommendations from a World Bank study, the plan includes actions to improve alternative financing channels, promote inclusive digital services, and support the growth of local Fintech businesses, especially those led by women. It also aligns with broader reforms being led by the Central Bank of West African States (BCEAO) to enhance the regional regulatory environment and promote innovation through national-level initiatives.

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[15] African Development Bank. (2022). Green Bank Initiative: Supporting African banks to finance green growth. https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/green-bank-initiative
The AfDB's Green Bank Initiative enhances local bank capacity to fund clean energy and climate-resilient projects.

[16] U.S. Department of Commerce. (2022). Renewable Energy in Côte d'Ivoire - Trade.gov.
https://www.trade.gov/market-intelligence/cote-divoire-renewable-energy
This report discusses renewable energy opportunities in Côte d'Ivoire and U.S. support for financing mechanisms.

[17] World Bank. (2022). Strengthening the Fintech Ecosystem in Côte d'Ivoire.
https://www.worldbank.org/en/news/feature/2022/05/31/strengthening-the-fintech-ecosystem-in-cote-d-ivoire
This World Bank report provides a roadmap to improve fintech and digital financial inclusion in Côte d'Ivoire

Reducing financial barriers—by making banking more accessible, supporting low-risk green investments, and encouraging more flexible financing solutions—will be crucial for Côte d'Ivoire to meet its rural electrification goals and to scale up the use of solar micro-grids.

1.5 Enabling Environments For Energy Finance: The Role Of Policy and Regulation

Effective policy and regulatory frameworks are fundamental in creating an appropriate environment conducive to the growth of green renewable energy initiatives. Globally, successful strategies have demonstrated that clear, consistent, and supportive policies can really make the difference and enhance investments in clean energy infrastructure[18].

This is particularly relevant for developing countries, where attracting private investment in clean energy often depends on the strength of national climate and energy policies. The IMF has shown that countries with clear long-term strategies—such as defined energy targets, guaranteed revenue streams through tools like power-purchase agreements, or incentive mechanisms—tend to receive more foreign investment in renewables. In the case of Côte d'Ivoire, which has strong solar potential and ambitious rural electrification goals, improving the policy environment could help reduce investor risk and make it easier to mobilize private capital[19]. For solar micro-grids to scale in rural areas, policy clarity and financial predictability will be just as important as technology and infrastructure.

In 2022, the World Bank approved a $300 million program to expand and modernize Côte d'Ivoire's electricity grid, with a focus on underserved northern and western

[18] International Monetary Fund. (2020). Fiscal Policies for Sustainable Development: Investment in Renewable Energy. This IMF study highlights how supportive policy frameworks, including guaranteed tariffs and stable investment rules, help attract foreign capital in renewable energy. https://www.imf.org/en/Publications/WP/Issues/2020/03/16/Fiscal-Policies-for-Sustainable-Development-Investment-in-Renewable-Energy-49183

[19] IRENA. (2016). Policies and Regulations for Renewable Energy Mini-Grids. This report explores how countries can reduce off-grid energy investment risk by establishing mini-grid specific policies. https://www.irena.org/publications/2016/Oct/Policies-and-regulations-for-renewable-energy-mini-grids

regions[20]. The project, called NEDA, aims to connect over 1.8 million people and improve the performance of the national utility, CI-Energies, through digital tools and smarter grid management. It supports ongoing national efforts like PEPT and PRONEX, which focus on reducing connection costs and extending grid coverage. Beyond access, NEDA strengthens the grid's reliability and resilience, aligning with the country's broader development goals.

Currently, despite the progress in Côte d'Ivoire, the country still faces some energy challenges. The first one is the access to electricity: the country needs on average 475 000 new connections annually for universal access within 2030. The current energy sources also pose a challenge, with solar that only represents 1% of them. Last, energy usage is also problematic since more than 70% of the households rely on biomass for cooking and use butane gas.

Since energy poverty is most severe in rural areas, targeted legal and regulatory reforms are essential to attract investment and support viable solutions in those communities, thus reducing the risks associated with rural electrification[21].

Côte d'Ivoire is often cited as a reference in West Africa for its approach to independent power production (IPP). Since the liberalization of its energy sector in the 1990s, the country has developed a regulatory model that encourages private investment in electricity generation while keeping the grid under public control. This public-private balance has helped secure long-term supply contracts and attract private capital into large-scale energy infrastructure. However, the model is still mostly focused on grid-connected thermal and hydro projects, while small-scale renewable solutions—like solar micro-grids—remain under-supported.

In recent years, Côte d'Ivoire has taken steps to improve its legal and regulatory framework for electricity, aiming to make the sector more attractive to private investors. A significant reform came with Law No. 2014-132, which reorganized the electricity

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[20] World Bank. (2022). Côte d'Ivoire Electricity Access and Renewable Energy Expansion Project (NEDA). The NEDA project supports national efforts to enhance electrification and reliability of the grid through digitalization and infrastructure financing.
https://projects.worldbank.org/en/projects-operations/project-detail/P176776

[21] World Bank. (2021). Improving the Enabling Environment to Expand Energy Access in Sub-Saharan Africa. This study explains how targeted reforms and tariff revision attract private actors in off-grid energy in Africa.
https://openknowledge.worldbank.org/handle/10986/36007

market and clarified the roles of public and private actors[22]. This was followed by Decree No. 2016-781, which set out detailed rules on licensing procedures for electricity generation, transmission, and distribution. The government has also worked to revise its tariff structure, moving toward greater transparency and cost-reflectiveness. While these changes have created a more stable environment for independent power producers (IPPs), further progress is needed to ensure that smaller, off-grid renewable energy projects—such as solar micro-grids—are also supported by clear and enabling regulation.

To attract both local and international investment in rural solar micro-grids, Côte d'Ivoire's regulatory efforts must look beyond large-scale energy projects and begin to address the specific challenges and financial realities faced by smaller, decentralized energy providers.

[22] République de Côte d'Ivoire. (2014). Loi n°2014-132 portant réforme du secteur de l'électricité. This national law restructured the Ivorian electricity sector, formalizing IPP roles and regulatory processes. https://www.ansut.ci/images/documents/Loi-2014-132-reforme-secteur-electricite.pdf

CHAPTER 2 – RESEARCH DESIGN

2.1 Research Objectives

This research aims to understand how banks and financial institutions can support the scalable deployment of solar micro-grids for rural electrification in Côte d'Ivoire.

As we already showed, this question is especially relevant in the context of the country's efforts to reach universal energy access and reduce rural poverty, while also transitioning toward sustainable energy sources. Universal energy access is key in the socio-economic development of a country, as it directly impacts education, healthcare, productivity, and income-generating opportunities[23], particularly in rural areas. In Côte d'Ivoire, where a large portion of the population still lacks reliable access to electricity, solar micro-grids represent a promising solution — especially in remote communities where grid extension is economically unfeasible. However, the scalability of these systems depends not only on technology, but also on the availability of tailored financial mechanisms and institutional support[24]. This makes the involvement of banks and financial institutions a critical component of the solution.

To answer this question, the empirical section is divided in two components: first, a quantitative regression will be carried out to explore the relationship between rural electrification rates and poverty reduction. The aim is to provide evidence that access to electricity is linked to broader social and economic development — a key argument in favour of increasing investment in this sector.

Second, two qualitative case studies will be included as well to demonstrate the potential of the installation of solar micro-grids. The goal of these case studies is to show how such projects are financed practically, how rural communities can access these solutions, and what practical role financial institutions may play in enabling the implementation of the projects.

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[23] Access to energy supports multidimensional development outcomes.
World Bank. (2018). Tracking SDG7: The Energy Progress Report. https://trackingsdg7.esmap.org

[24] Scalability challenges in off-grid projects often stem from weak financial support and fragmented institutional backing. IRENA. (2016). Unlocking Renewable Energy Investment: The Role of Risk Mitigation and Structured Finance. https://www.irena.org/publications/2016/Jun/Unlocking-renewable-energy-investment

Together, these two approaches will offer both a macro-level perspective on the importance of rural electrification and a micro-level view of how, nowadays, financing these kind of projects works in practice. This will help to identify gaps, strengths, opportunities and actionable recommendations.

2.2 Quantitative Analysis – Regression

A mixed approach – quantitative and qualitative – will be used to support this research.

The first one, which will be useful to justify the need for greater investments in the energy sector in Côte d'Ivoire, especially in remote, rural communities, involves a regression analysis of how electrification rates help in the reduction of poverty and, consequently, in the improvement of living conditions, in a country.

The analysis draws on World Bank data covering the period from 2000 to 2021. Three key variables are considered:

- The percentage of the rural population with access to electricity (used as the independent variable).
- The poverty headcount ratio (percentage of people living under $2.15 per day, used as the dependent variable and as a proxy to measure extreme poverty).
- The GDP per capita (used as a control variable to account for general economic growth. In other words, it explains changes in the general economic context).

These variables have been selected to capture both the access to basic infrastructure (basically energy access) and the broader socio-economic context[25], allowing a clearer view of whether electricity access contributes to improved living conditions beyond general economic growth.

The relationship between the variables will be estimated using the following linear regression:

$$\mathbf{Poverty_t = \beta_0 + \beta_1 \cdot Electricity_t + \beta 2 \cdot GDPpc_t + \epsilon_t}$$

Where:

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[25] This triangulation of electricity, income, and poverty is widely used in development economics. Blimpo, M. P., & Cosgrove-Davies, M. (2019). Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact. World Bank. https://openknowledge.worldbank.org/handle/10986/31333

- $Poverty_t$ is the poverty headcount ratio in year t, defined as the percentage of the population living on less than $2.15 per day.
- $Electricity_t$ is the rural electrification rate in year t, measured as the percentage of the rural population with access to electricity.
- $GDPpc_t$ is GDP per capita in current US dollars in year t.
- β_0 is the intercept of the model.
- β_1 and β_2 are the coefficients to be estimated, representing the relationship between poverty and each explanatory variable.
- ϵ_t is the error term.

This regression is expected to show a negative correlation between the two main variables[26] – electrification rate and percentage of population living under $2/per day – meaning that electrification rate growth may be associated with less people living in extreme poverty. This kind of statistical relationship would offer concrete evidence that improving energy access is not only a matter of infrastructure development, but also a key enabler for advancing social equity and economic inclusion.

These findings would also directly align with the goals of the United Nations 2030 Agenda for Sustainable Development, particularly Goal 1 (No Poverty) and Goal 7 (Affordable and Clean Energy for All). By showing how energy access contributes to poverty reduction, the analysis reinforces the argument that rural electrification should be a strategic priority for governments, development institutions, and especially banks and financial actors, who have a critical role in mobilizing and structuring the capital needed to scale up solutions like solar micro-grids.

2.3 <u>Qualitative Analysis – Case Study</u>

The second component of our empirical research is a qualitative case study approach to understand the pragmatic realities of solar power electrification in Côte d'Ivoire. The qualitative component is therefore built on two well-documented and diverse case studies:

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[26] Previous research suggests a robust link between electricity access and poverty reduction, even after accounting for macroeconomic factors.
Cook, P. (2011). Infrastructure, rural electrification and development. Energy for Sustainable Development, 15(3), 304–313. https://doi.org/10.1016/j.esd.2011.07.008

the Elokato-Bingerville solar micro-grid feasibility study and the Boundiali Solar Power Station, both of which are sterling examples of solar energy deployment in the nation.

The first case—Elokato-Bingerville—is based on a decentralized and small-scale solar micro-grid project for off-grid rural electrification. It allows us to review the local planning, economic feasibility, and business model of a system designed to serve villages outside the national grid. Alternatively, the Boundiali project is a grid-connected, utility-scale solar power plant demonstrating a national strategy for integrating renewable energy into Côte d'Ivoire's power mix. Collectively, these studies offer complementary knowledge regarding the multi-level strategies employed to promote energy access in the country[27].

These studies were selected because they offer concrete and open technical records and cost estimates, enabling one to explore diverse relevant themes. These are: project design and execution methodologies in rural and utility-scale settings; Financing mechanisms, including public-private partnerships, donor participation, and concessional finance; Institutional and regulatory considerations that enable or deter deployment; Operations, training, and local capacity development activities; Sustainability strategies, such as tariff models and community engagement.

Furthermore, the research identifies the means by which rural solar programs can be integrated into the broader energy and development plans of Côte d'Ivoire, as well as those contained in the PRONER program and the Sustainable Development Goals (SDGs). By the use of these two diametrically opposed projects, this study aims to elucidate both the potential and limitation of solar electrification projects. The Elokato micro-grid offers an overview of bottom-up energy supply structures that value community needs and decentralized structures. The Boundiali project, on the other hand, shows the potential of incorporating large-scale renewable power into the national energy planning through international partnerships and coordinated funding.

Ultimately, this comparative case-based approach allows us to identify practical gaps within the electrification process, pilot different financing and institutional methods, and

[27] Diverse project scales illustrate the interplay between national infrastructure plans and community-based solutions.
USTDA. (2019). USTDA Supports Rural Electrification Project in Côte d'Ivoire. https://ustda.gov/ustda-supports-rural-electrification-project-in-cote-divoire

propose targeted recommendations regarding how banks, governments, and development partners can strengthen support for scale-up of clean energy systems in Côte d'Ivoire.

2.4 Limitations

Although the research design integrates both the quantitative and qualitative methods to ensure a thorough explanation of rural electrification in Côte d'Ivoire, there are various limitations that should be taken into account. To begin with, the quantitative analysis utilizes country-level rural electrification data for the period 2000–2021. Although this provides a rough sketch of long-run trends, the limited number of annual observations diminishes the statistical robustness of the findings and restricts the application of more sophisticated econometric techniques. Furthermore, aggregate national data neglects regional and local variation in electricity access, which may vary significantly across different rural areas.

Qualitatively, the original research design required a case study from primary data collected from the Nextel firm, which sadly could not be executed due to the unavailability of access to company officials. The empirical section hence relies exclusively on desk research on two publicly documented solar energy projects: the Elokato-Bingerville micro-grid and the Boundiali Solar Power Station. Though such instances are beneficial and revealing, the absence of fieldwork and interviewing stakeholders bars the full range of experiential depth, forces of community, and on-the-ground operational challenges. In addition, conclusions from two case studies are representative examples of overall trends and financing mechanisms within the sector in Côte d'Ivoire.

CHAPTER 3 – EMPIRICAL FINDINGS AND ANALYSIS

3.1 Introduction to The Analysis

This section aims to empirically explore the relationship between rural electrification and poverty reduction in Côte d'Ivoire. As discussed in the previous chapters, universal energy access is widely recognized as a fundamental pillar of socio-economic development for a country, and for this reason it is also one of the goals of the 2030 UN Agenda (Goal 7: affordable and clean energy for everyone)[28]. This makes of it an important target to reach as soon as possible for the well being of everyone. In rural areas in particular, access to electricity can improve living conditions by enabling productive activities, creating job opportunities, increasing access to education and healthcare services (thus also improving life expectancy of people), and reducing time spent on basic survival tasks such as collecting fuel or fetching water.

These are all valid reasons for banks and financial institutions to invest in these kinds of projects and make them 'bankable' for local people. To support this argument with data, a quantitative analysis is conducted using a linear regression model. The objective is to test whether an increase in rural electrification rate is associated with a decrease in extreme poverty, and to what extent this relationship holds when controlling for overall economic growth.

To estimate the relationship, an Ordinary Least Squares (OLS) regression model is applied[29]. This method was chosen for its interpretability, transparency, and suitability for small time-series datasets. The analysis also rests on standard linear model assumptions, including linearity, homoscedasticity, and independence of errors.

By combining these indicators in a single regression model, the objective is to isolate the effect of rural electrification from that of broader economic growth. The results will

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[28] United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. United Nations.
This document outlines the 17 Sustainable Development Goals (SDGs), including Goal 7 on energy and Goal 1 on poverty.
https://sdgs.un.org/2030agenda

[29] Wooldridge, J. M. (2013). Introductory econometrics: A modern approach (5th ed.). Cengage Learning.
This textbook provides a comprehensive explanation of OLS and its assumptions, widely used in empirical research.

help assess the potential of energy access as a mean to reduce poverty, thus providing additional justifications for the involvement of banks, development actors and financial institutions in financing scalable rural energy solutions.

3.2 Model Specification

To better understand the relationship between rural electrification and poverty reduction in Côte d'Ivoire, a quantitative approach based on Ordinary Least Squares (OLS) was adopted. This method, commonly used in economics and social sciences, allows the estimation of linear relationships between variables and is particularly suitable in contexts with limited data availability. In this case, the regression is a preliminary process to hypothesis testing that higher rural access to electricity is statistically associated with lower rates of extreme poverty, controlling for wider economic trends using GDP per capita. Although the small number of observations limits the scope of the analysis, the model provides us with an exploratory empirical foundation to supplement the qualitative component of the thesis.

The regression is defined by the following linear equation:

$$\textbf{Povertyt} = \beta 0 + \beta 1 \cdot \textbf{Electricityt} + \beta 2 \cdot \textbf{GDPpct} + \epsilon t$$

Where:

- $Poverty_t$ is the poverty headcount ratio in year t, defined as the percentage of the population living on less than $2.15 per day.
- $Electricity_t$ is the rural electrification rate in year t, measured as the percentage of the rural population with access to electricity.
- $GDPpc_t$ is GDP per capita in current US dollars in year t.
- β_0 is the intercept of the model.
- β_1 and β_2 are the coefficients to be estimated, representing the relationship between poverty and each explanatory variable.
- ϵ_t is the error term.

This model aims to assess whether increased energy access in rural areas correlated with lower poverty levels, after accounting for changes in general economic conditions.

The dependent variable of the model is the poverty headcount ratio, which aims at the proportion of the population living under the international poverty line of $2.15 a day (in 2017 PPP terms)[30]. This indicator, defined by the World Bank, has been widely adopted as an international benchmark[31] to estimate extreme poverty and is also aligned with Sustainable Development Goal 1 (No Poverty). Using this indicator allows the study to be consistent with international definitions and also facilitates comparability with other empirical studies in the development literature.

The primary independent variable is the electrification rate, selected as a proxy for access to overall infrastructure and public facilities among marginalized groups. Various studies have shown that increased access to electricity is associated with better education levels, higher levels of healthcare delivery quality, and household welfare in general[32]. In rural regions of Côte d'Ivoire, where it is much too expensive to extend the grid, decentralized energy technology such as solar micro-grids might play a life-altering part. The variable that includes this also captures the broader hypothesis that enhanced access to energy facilitates economic empowerment and reduces structural barriers correlated with poverty.

To account for the overall economic performance and growth in income within the country, GDP per capita is included as a control variable. This accounts for macroeconomic conditions that influence poverty outcomes independently and captures country-level economic performance and income growth. For instance, a boom in commodity prices at the national level or investment from abroad might raise incomes and reduce poverty without any improvement in infrastructure. By adding GDP per capita, the model tries to isolate the poverty-reducing impacts of electrification from those due to overall economic growth.

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[30] World Bank. (2022). Poverty and inequality platform. The World Bank.
The $2.15/day threshold (in 2017 PPP) is the updated international poverty line used for global poverty comparisons.
https://pip.worldbank.org/home

[31] World Bank. (2022). Poverty headcount ratio at $2.15 a day (2017 PPP) (% of population) – Côte d'Ivoire. https://data.worldbank.org/indicator/SI.POV.DDAY?locations=CI
World Bank's core poverty indicator used to track progress on SDG 1 across countries, based on 2017 PPP values.

[32] IEA. (2022). World Energy Outlook 2022. International Energy Agency.
https://www.iea.org/reports/world-energy-outlook-2022 — Details how energy access drives socioeconomic improvements in low-income regions.

The regression was performed in Python with the Pandas library being used for data manipulation, matplotlib and seaborn for plotting, and the statsmodels package being used for econometric analysis[33]. The World Bank data was received in CSV format, and after merging the three respective datasets (poverty headcount, rural electrification rate, and GDP per capita), the dataset was cleaned to remove years with missing values. This resulted in a final dataset of five observations (2002, 2008, 2015, 2018, 2021). While small, this sample does contain years with great variation in all three variables, including periods of economic growth and post-war recovery.

Despite the limited dataset and optimal interpretation of the regression as exploratory, OLS was employed because it provides a convenient way of discerning potential linear relationships between selected variables. The model is not intended to say anything about causality but rather whether there exists a statistically significant relationship between higher electrification and reduced poverty in Côte d'Ivoire. This statistical foundation can underlie subsequent qualitative interpretation and policy discussion in later chapters.

3.3 Descriptive Statistics

The dataset used for this analysis was constructed by combining publicly available time-series data from the World Bank. As already mentioned, three key indicators were selected, covering the years from 2000 to 2021: the percentage of the rural population with access to electricity (Electrification Rate), the poverty headcount ratio (percentage of the population living under $2.15 per day), and GDP per capita in current US dollars.

After importing the datasets into a Python Kernel, the data were cleaned and filtered to include only observations for Côte d'Ivoire. Missing values – especially in the poverty variable – reduced the number of overlapping data points to five years. While limited, this overlap still allows for a preliminary statistical analysis of the relationship between energy access and poverty. *Table 1* summarizes the variables used in the regression.

[33] McKinney, W. (2018). Python for data analysis: Data wrangling with Pandas, NumPy, and IPython (2nd ed.). O'Reilly Media. — A key reference on using Python tools for data cleaning, visualization, and analysis.

	Year	Electrification Rate (%)	Poverty Rate (% under $2.15/day)	GDP per Capita (current US$)
2	2002	26.8	29.1	967.815864
8	2008	35.6	34.4	1583.970667
15	2015	39.2	33.4	1814.718551
18	2018	40.4	11.5	2130.866194
21	2021	45.2	9.7	2455.981276

Table 1: Variables Used in The Regression

Although the sample is limited to five observations, the table suggests a potential inverse relationship between electrification and poverty: as rural electricity access increased from 26.8% to 45.2%, the share of the population living under $2.15/day fell sharply from 29.1% to 9.7%. Meanwhile, GDP per capita also rose steadily, justifying its inclusion as a control variable in the regression model to account for macroeconomic effects.

In addition to the year-by-year trends, basic descriptive statistics offer further insight into the underlying structure of the dataset and the behaviour of the variables under examination. Over the selected time period (2000-2021), the mean rural electrification rate in Côte d'Ivoire was approximately 37.44%, with a standard deviation of 6.87 percentage points. This means that the electrification rate deviated from the mean by around 7 points in both directions, which reflects a gradual but consistent increase in electricity access over time, without sudden fluctuations or shocks. The values, as we already noted, ranged from a minimum of 26.8% in 2002 to a maximum of 45.2% in 2021, which is coherent with an upward path in terms of access to energy across time. This trend can be observed in *Figure 3*.

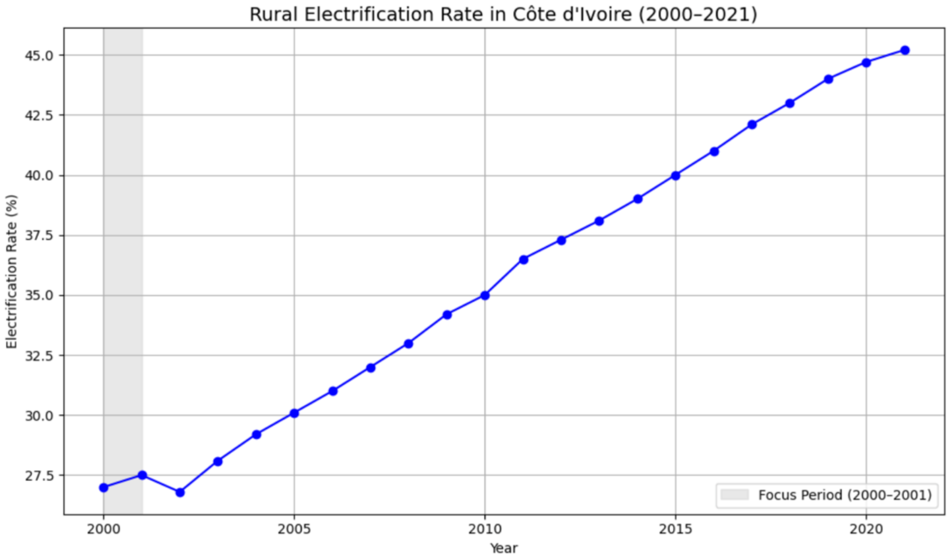

Figure 3: Rural Electrification Rate in Côte d'Ivoire (2000-2021)

The poverty headcount ratio, defined as the percentage of the population living under \$2.15 per day, showed a much higher level of variability. The mean value was 23.62%, but with a standard deviation of 12.07 percentage points, thus suggesting differences in poverty levels during the years. The lowest value was registered in 2021 (9.7%), while the highest in 2008 (34.4%). This elevated poverty level occurred during a fragile post-conflict period, following the first Ivorian civil war (2002–2007), when the country was still struggling with deep political divisions and weakened institutions. Such episodes of instability highlight the vulnerability of poverty levels to external shocks, beyond economic or infrastructure factors alone. Coming back to our data, however, the country underwent substantial reductions in extreme poverty — especially in the second half of the observed period. These wide fluctuations suggest that poverty is influenced by a complex mix of factors, among which energy access may play an important, but not exclusive, role, which justifies the presence of GDP per capita as a control variable.

As for GDP per capita, the average value stood at \$1790.67, with a standard deviation of \$565.41. The variable increased steadily over the period, starting from just \$967.82 in 2002 and reaching \$2,455.98 by 2021. This steady growth in national income reinforces the importance of including GDP as a control variable in the regression model, as it allows us to isolate the effect of electrification on poverty from the general economic development trend. Without this control, we risk attributing to energy access some of the poverty reduction that may, in reality, result from macroeconomic growth.

In summary, the descriptive statistics point to clear patterns: a steady increase in electrification, an overall reduction in poverty, and substantial GDP growth. These trends align with Côte d'Ivoire's national development goals and support the relevance of the empirical inquiry. At the same time, the variation within each variable — especially poverty — highlights the importance of testing these relationships statistically, rather than assuming direct causality based on trends alone. The following sections will develop this analysis through a formal regression model, using the data described here.

Table 2 shows the results of the descriptive statistics.

	Year	Electrification Rate (%)	Poverty Rate (% under $2.15/day)	GDP per Capita (current US$)
count	5.00	5.00	5.00	5.00
mean	2012.80	37.44	23.62	1790.67
std	7.73	6.87	12.07	565.41
min	2002.00	26.80	9.70	967.82
25%	2008.00	35.60	11.50	1583.97
50%	2015.00	39.20	29.10	1814.72
75%	2018.00	40.40	33.40	2130.87
max	2021.00	45.20	34.40	2455.98

Table 2: Descriptive Statistics

3.4 Regression Results

The Ordinary Least Squares (OLS) model was executed using data from 2002 to 2021, with the aim of identifying the statistical relationship between rural electrification, poverty, and GDP per capita in Côte d'Ivoire. Building on the model previously outlined, this section presents the core regression results and interprets their meaning within the context of the country's development trajectory.

The output of the OLS model is reported in *Table 3*. As already stated, the dependent variable is the poverty headcount ratio, defined as the percentage of the population living on less than $2.15/day (2017 PPP). The independent variable is the rural electrification rate, measured as the percentage of the rural population with access to electricity. The control variable is GDP per capita in current USD, which accounts for broader macroeconomic effects.

OLS Regression Results

Dep. Variable:	Poverty Rate (% under $2.15/day)	R-squared:	0.971
Model:	OLS	Adj. R-squared:	0.942
Method:	Least Squares	F-statistic:	33.31
Date:	Tue, 15 Apr 2025	Prob (F-statistic):	0.0291
Time:	12:52:57	Log-Likelihood:	-10.151
No. Observations:	5	AIC:	26.30
Df Residuals:	2	BIC:	25.13
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-69.2820	22.491	-3.080	0.091	-166.055	27.491
Electrification Rate (%)	7.5712	1.378	5.495	0.032	1.643	13.500
GDP per Capita (current US$)	-0.1064	0.017	-6.359	0.024	-0.178	-0.034

Omnibus:	nan	Durbin-Watson:	3.024
Prob(Omnibus):	nan	Jarque-Bera (JB):	0.690
Skew:	0.434	Prob(JB):	0.708
Kurtosis:	1.401	Cond. No.	3.22e+04

Table 3: Ordinary Least Squared Model Output

The model exhibits a very high R-squared value of 0.971, indicating that 97.1% of the variation in poverty rates can be explained by the combined changes in rural electrification and GDP per capita. While this high explanatory power should be interpreted cautiously due to the small sample and the potential for multicollinearity between the independent variables, it does suggest that the model captures meaningful patterns in the data.

Among the key findings, we can see that the coefficient on the electrification rate ($\beta = +7.57$) was found to be positive and statistically significant at the 5% level. This means that an increase of one percentage point in the rural electrification is associated with a 7.57 percentage point increase in the poverty headcount ratio. At face value, this result is counterintuitive and contradicts both our theoretical expectations and prior empirical literature, according to which improved energy access is associated with poverty alleviation (IEA, 2022)[34]. There are several reasons why this result should be interpreted with extreme caution:

[34] International Energy Agency. (2022). Energy access outlook: SDG7 tracking report. IEA. https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2022
This report evaluates progress on SDG 7 and highlights the positive impact of electrification on poverty reduction, particularly in sub-Saharan Africa.

- Collinearity with GDP: As noted in the descriptive statistics section, both rural electrification and GDP per capita have taken a consistently increasing trend in Côte d'Ivoire over the period of the last two decades. While this is reflective of the overall economic development in the country, it poses a statistical issue known as multicollinearity when both variables are included in the same regression equation. Multicollinearity occurs when two or more independent variables are extremely highly correlated with one another, and thus it is hard to distinguish their separate effects on the dependent variable[35]. Practically, it leads to inflated standard errors, reduced statistical significance, and perhaps unstable coefficient estimates. As a result, the regression may incorrectly suggest that a variable (in this case, electrification) has a weaker or distorted effect on poverty than it actually does. In our model, the electrification coefficient could be partially "absorbing" the impact of GDP growth, or vice versa, thereby masking the true relationship.

  The high condition number (3.22e+04) further supports this hypothesis[36] of multicollinearity between the two variables.

- Lag effects: The benefits of electrification on poverty may take time to materialize. For example, infrastructure expansion may occur before households are financially able to fully benefit from it, or before local businesses respond to improved energy supply.

- Geographic targeting: It's also possible that during the observed years, electrification projects targeted the poorest and most remote areas, which had higher poverty levels to begin with. In that case, the positive coefficient does not imply causation but rather reflects the geographic distribution of projects.

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[35] Farrar, D. E., & Glauber, R. R. (1967). Multicollinearity in regression analysis: The problem revisited. The Review of Economics and Statistics, 49(1), 92–107. https://doi.org/10.2307/1927797
A foundational paper explaining how multicollinearity inflates variance in OLS regression and affects coefficient estimates.

[36] Farrar, D. E., & Glauber, R. R. (1967). Multicollinearity in regression analysis: The problem revisited. The Review of Economics and Statistics, 49(1), 92–107. https://doi.org/10.2307/1927797
A foundational paper explaining how multicollinearity inflates variance in OLS regression and affects coefficient estimates.

- Small sample bias: With only five observations, even a single outlier year (e.g. post-crisis 2008 or pandemic-era 2021) can skew results significantly.

On the other hand, the coefficient on GDP per capita is statistically significant and theoretically plausible. The negative sign indicates that with every additional dollar of GDP per capita, the poverty headcount decreases by approximately 0.11 percentage points. This reaffirms the long-standing evidence that economic growth is central to poverty alleviation, especially in low-income countries where even small income increases can have large effects on welfare.

This finding justifies the decision to include GDP per capita as a control variable: it enables us to separate the unique contribution of the infrastructure and access variables from more diffuse macroeconomic effects. It also suggests that increases in income alone could have been responsible for a large portion of the poverty decline in this period — a relevant consideration for financial institutions, which tend to emphasize macroeconomic trends in evaluating investment risk.

The regression intercept (β_0) estimates the poverty headcount ratio when the rural electrification rate and GDP per capita are both zero. Nevertheless, given that such levels are not economically relevant to the case of Côte d'Ivoire—where the two variables have always been strictly positive—the intercept does not have any practical interpretation. Its inclusion still remains required for the statistical specification of the Ordinary Least Squares (OLS) model because it centers the regression line and maintains the sum of squared residuals at a minimum.

No other severe violations of OLS assumptions appear in the output: the F-statistic is significant ($p < 0.05$), the residual standard error is reasonably low, and there is no evidence of heteroskedasticity in the residual plot.

To test for strength and prevent possible distortion caused by multicollinearity, an alternative regression model with a reduced setup was also run, that one excluding the GDP per capita as a control. What was hoped to be realized there was the untangling of the straightforward causality between poverty and rural electrification from any disturbing element of macro growth trends. The results of this second model were closer to theoretical predictions: the coefficient on the level of electrification was negative (β = –1.08), implying that rural improvements in access to electricity are associated with reductions in extreme poverty. Although the coefficient was not statistically significant at standard levels ($p = 0.267$), most probably because of the small sample size and limited statistical power, the effect direction is in support of the overall hypothesis that electrification promotes poverty alleviation.

While this second model has a lower R-squared value of 0.382 and is not statistically significant due to the small sample size, it aligns better with theoretical expectations and existing literature on energy access and development. This suggests that the positive coefficient observed in the first model may indeed be the result of multicollinearity between electrification and GDP per capita. By scaling down the model, we were better able to pick up on the intuitive and evidence-based inverse relationship between poverty and access to energy. While these results still must be read cautiously since we have small numbers of data points, they suggest that electricity access does play some role in poverty reduction—above all, once it is evaluated separately from other economic cycles.

In terms of statistical significance, the full model reports p-values of 0.032 for electrification and 0.024 for GDP per capita, indicating that both variables are statistically significant at the 5% level when taken together. However, given the high correlation between the two explanatory variables, these results should be interpreted cautiously.

In both models, the sign of the relationship between electrification and poverty is a key takeaway. Despite the lack of statistical significance in the simpler model, its negative coefficient is coherent with broader development theory: improved access to electricity facilitates productivity, education, healthcare access, and entrepreneurship—all factors that contribute to poverty reduction.

Coming then to the visual representations of the data, *Figure 1* shows a scatterplot of the rural electrification rate against the poverty headcount ratio (% of population under $2.15/day), based on the simplified regression model that excludes GDP per capita.

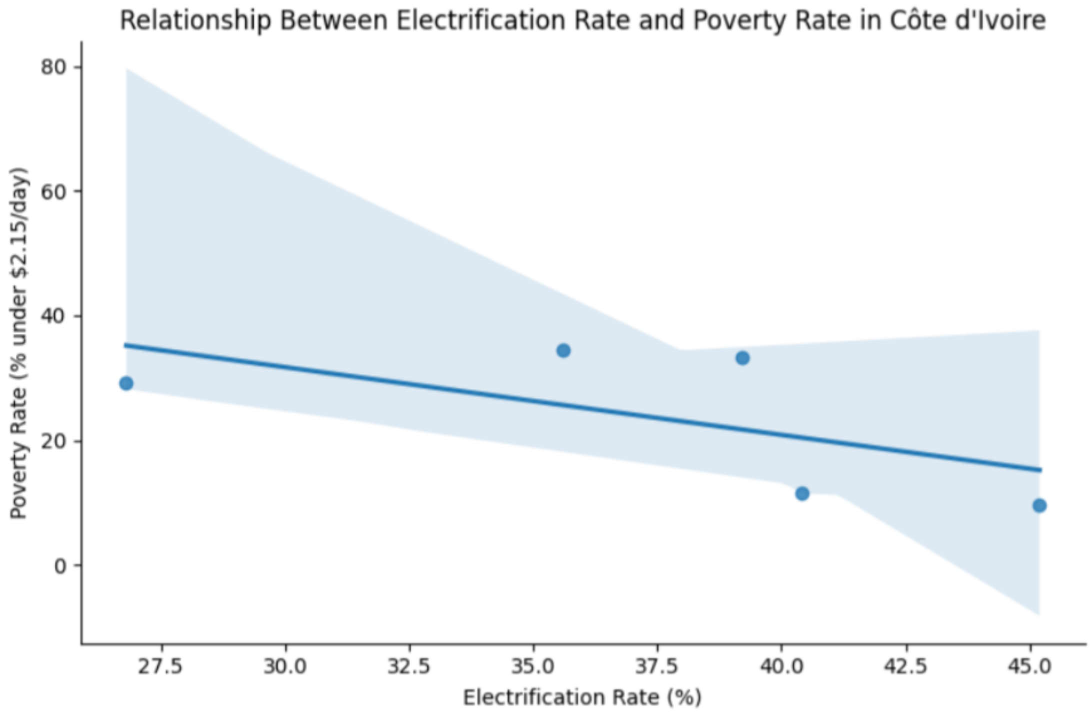

Figure 1: Relationship between Electrification Rate and Poverty Rate in Côte d'Ivoire

The scatterplot shows the five data points observed with the rural electrification rate on the x-axis and the percentage of individuals living on less than $2.15 per day on the y-axis. A fitted regression line is plotted above the data with a shaded 95% confidence band around the line.

The negative slope of the regression line confirms the hypothesized theoretical relationship: higher levels of rural electrification are associated with lower poverty rates. This graphical trend confirms the hypothesis that rural electricity access will lead to a decline in extreme poverty. Although the effect is not statistically significant in the regression (as mentioned above), the graph again indicates that the direction of the association conforms to development theory and previous empirical studies.

The point distribution also should be mentioned. Small as the sample is, the direction over time for the points does reflect the trend of Côte d'Ivoire's overall development initiatives: investment in infrastructure has driven electricity penetration to rural areas, and this probably has contributed to poverty reduction among scattered communities. As a bonus, the chart even provides an estimate of the scale of the transition. For example, the change from some 27% electrification to over 45% can be observed to correspond to a reduction in poverty from approximately 30% to below 10%. This order of magnitude — although not very big — indicates the potential for development of electrification schemes.

The wide confidence interval along the regression line is also useful to know how to interpret. It indicates serious statistical inaccuracy in the line slope estimate as a direct effect of the low sample size. In practice, it means we are less sure of the actual strength of the connection between electrification and poverty even if direction of effect overall is evident. However, the downward slope of the line — and not upward, as in the full model — is visual confirmation of the hypothesis that the original positive coefficient was likely biased by multicollinearity.

Overall, Figure 1 is not only a graphical validation of the regression findings but also a transmission tool for policy significance. The graph conveys a compelling narrative even in the absence of high statistical significance. Rural electrification expansion may be a vital lever for poverty reduction in Côte d'Ivoire, and thus ought to be accorded more priority by banks, policymakers, and development institutions.

Figure 2 illustrates the trajectory of rural electrification, poverty, and GDP per capita in Côte d'Ivoire between 2002 and 2021.

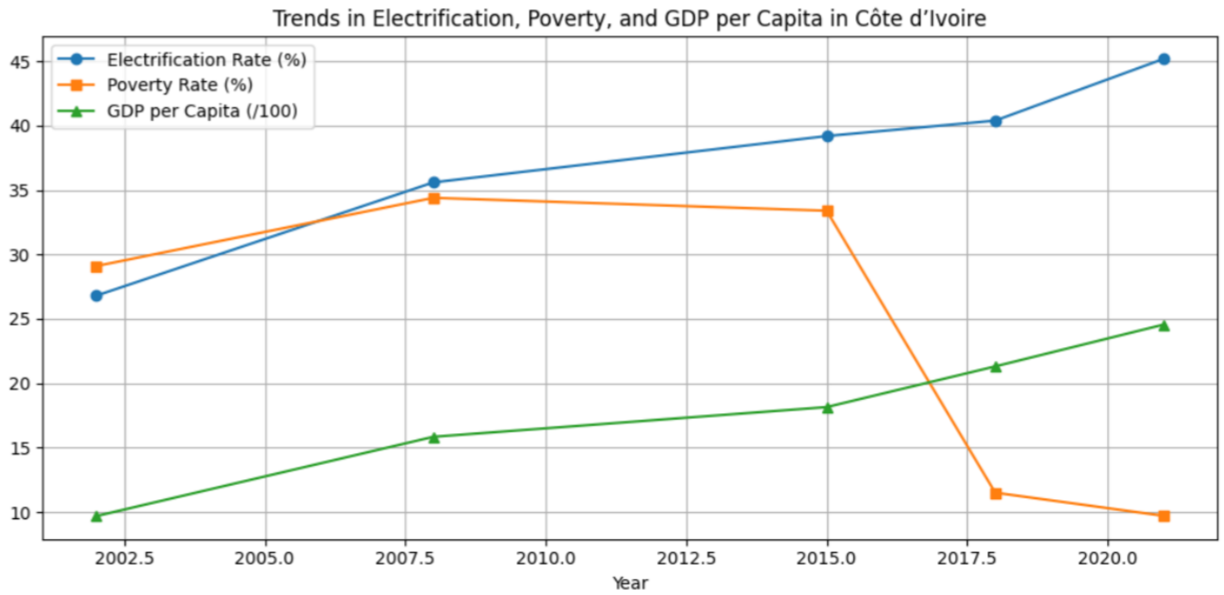

Figure 2: Trends in Electrification, Poverty, and GDP per Capita in Côte d'Ivoire between 2002 and 2021

As is apparent, the rate of electrification was unmistakably on an upward trend, rising from 27% in 2002 to over 45% in 2021. This could reflect national development operations, particularly the implementation of particular energy programs such as PRONEX (to extend and densify grids) and PEPT[37] (targeting to reduce connection costs for low-income households). These initiatives likely helped significantly to expand electricity access in rural areas far from the capital.

GDP per capita also increased steadily during the period, from less than $1,000 to nearly $2,500. This trend reflects broader economic recovery and post-conflict growth, suggesting a generally more positive macroeconomic climate.

In contrast, poverty levels were relatively high and stable until 2015, fluctuating between 30%–34%. After 2015, however, there is a dramatic and steep decline, with the poverty rate falling as low as 9.7% by 2021. This decline aligns with the subsequent phases of rural electrification extension and sustained economic growth, and it suggests that the effects of infrastructure investment can be slow to be fully manifested in poverty reductions.

These coinciding trends demonstrate one of the big problems covered by the regression: as both GDP and electrification rise over time, it becomes difficult to tease out their independent contributions to reducing poverty. That convergence is what justifies experimenting with a truncated regression model dropping GDP as a control, to be able to isolate more clearly the pure effect of electrification. But the general principle remains expanded access to energy, along with sustained economic advancement, appears to be associated with substantial poverty declines.

3.4.1 <u>Lagged Variable Specification</u>

To examine whether the impact of rural electrification on poverty can be persistent, another model specification was estimated using a lagged independent

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[37] World Bank. (2022). Côte d'Ivoire – National Electrification Program (PRONEX) and Electricity for All Program (PEPT). https://projects.worldbank.org/en/projects-operations/project-detail/P164145
→ World Bank documentation on major electrification initiatives in Côte d'Ivoire designed to reduce connection costs and increase energy access in rural areas.

variable. In this case, the rural electrification rate in year t–1 was used to predict poverty in year t, though still controlling for GDP per capita. This change reflects possible lagged impacts of infrastructure deployment on household income and wellbeing[38].

The result of the lagged model remains largely consistent with the base specification. The lagged electrification coefficient is positive (0.1141) but statistically insignificant (p = 0.962). GDP per capita continues to be negatively correlated with poverty, although also statistically insignificant here. The R-squared is 0.862 and still shows that the model accounts for a lot of variance, but the high condition number (1.37e+04) once more suggests potential multicollinearity or numerical instability due to the small sample size.

Despite the insignificance, this robustness check is helpful: it shows once more that short-run effects of electrification may not be measurable and helps to check that the impact evaluations of energy projects must have a longer time horizon. Future studies would be facilitated by panel data for regions or more time points in order to better measure lagged development outcomes. *Table 4* summarizes the output of the regression.

```
                                 OLS Regression Results
==========================================================================================
Dep. Variable:     Poverty Rate (% under $2.15/day)   R-squared:                   0.862
Model:                                          OLS   Adj. R-squared:              0.587
Method:                               Least Squares   F-statistic:                 3.128
Date:                              Thu, 29 May 2025   Prob (F-statistic):          0.371
Time:                                      16:39:11   Log-Likelihood:            -11.541
No. Observations:                                 4   AIC:                         29.08
Df Residuals:                                     1   BIC:                         27.24
Df Model:                                         2
Covariance Type:                          nonrobust
==============================================================================================
                                coef    std err          t      P>|t|      [0.025      0.975]
----------------------------------------------------------------------------------------------
const                        87.3205     29.222      2.988      0.206    -283.979     458.620
Electrification Rate Lagged   0.1141      1.889      0.060      0.962     -23.893      24.121
GDP per Capita (current US$) -0.0346      0.031     -1.132      0.461      -0.423       0.354
==============================================================================
Omnibus:                          nan   Durbin-Watson:                   3.352
Prob(Omnibus):                    nan   Jarque-Bera (JB):                0.402
Skew:                          -0.436   Prob(JB):                        0.818
Kurtosis:                       1.715   Cond. No.                     1.37e+04
==============================================================================
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Table 4: OLS Output with Lagged Variable Specification

[38] Van de Walle, D., Ravallion, M., Mendiratta, V., & Koolwal, G. (2015). Long-term impacts of household electrification in rural India. World Bank Policy Research Working Paper No. 6527. https://doi.org/10.1596/1813-9450-6527
This study shows how the effects of rural electrification on poverty and income materialize over a longer period, justifying the use of lagged variables.

Then, Figure 4 illustrates the contrasting trajectories of poverty and rural electrification (t−1).

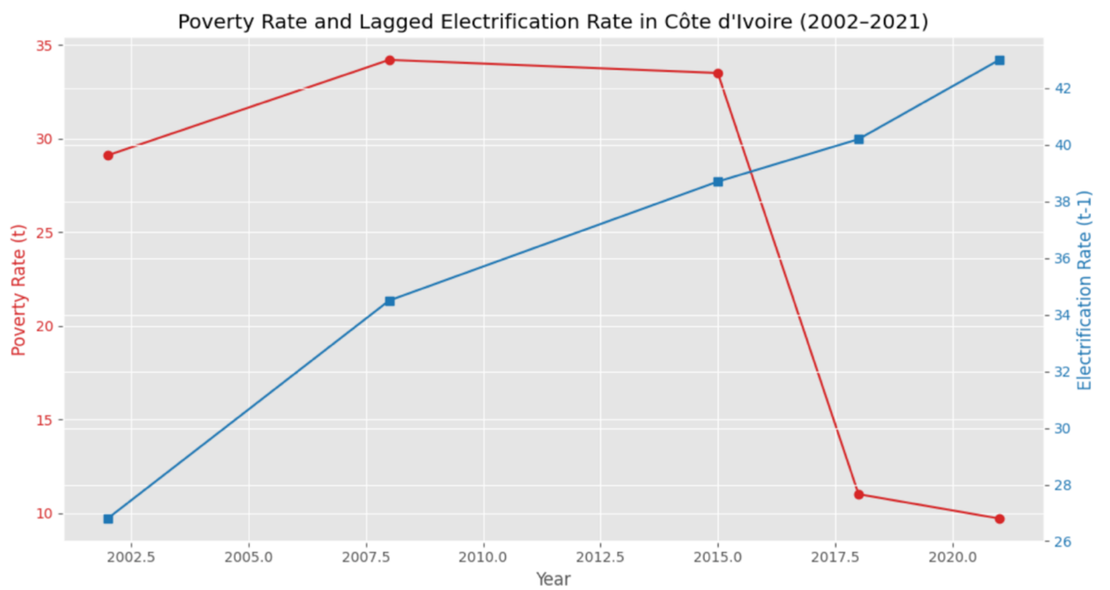

Figure 4: Poverty Rate and Lagged Electrification Rate in Côte d'Ivoire (2002-2021)

While electrification rates increased consistently, poverty remained high until 2015, after which a dramatic drop was observed. This temporal divergence supports the hypothesis that the effects of electrification on poverty are not immediate and may only be observed after a lag — a notion tested via the lagged regression specification discussed above.

3.5 Discussions

The regression estimates examined in this chapter, although based on a fairly small number of observations, provide a useful point of departure for thinking about the connection between rural electrification and poverty in Côte d'Ivoire. To begin with, it was anticipated that greater access to electricity in rural areas would be accompanied by lower poverty levels. This is based on a large body of evidence that considers access to energy as one of the pillars of sustainable development—especially in low-income, rural communities where infrastructure is poor and living standards remain precarious

Yet the results of the first regression model seem to tell a different story. Rather than supporting the original hypothesis, the coefficient for rural electrification turned out to be positive and statistically significant. This would suggest that as electricity access rises, poverty also increases – a conclusion that seems counterintuitive if we think about the development theory or the policy experience. However, before drawing strong conclusions, this finding needs to be treated with caution. As discussed earlier in the chapter, the model may have been distorted by multicollinearity, particularly due to the strong correlation between electrification and GDP per capita. Both variables followed similar upwards trends over time, and this overlap can lead to inaccurate or misleading coefficient estimated.

To unpack this further, a second regression was run excluding GDP per capita from the equation. This simplified model, while statistically weaker and lacking in precision due to the small sample size, produced a negative coefficient for electrification – now suggesting that greater access to electricity is associated with lower poverty levels - coherent with the initial theoretical expectations and with the broader direction of existing research. Although not statistically significant, likely due to the small number of observations, the result still supports the idea that rural electrification contributes to improving living conditions, when analyzed apart from the confounding influence of overall economic growth.

These contradictory results point towards serious problems in how development results are measured and interpreted. To begin, infrastructure access and poverty aren't necessarily linear and instantaneous correlations. Perhaps there will be lags in time before the effects of electrification make their way into measurable changes in income or happiness. For example, even after a household is connected to electricity, there may be lag before they can afford appliances[39], start a small enterprise, or use value-added services like cooling for medical purposes or lighting for schools. This lagged effect notion makes especially true sense in rural Côte d'Ivoire, where other support systems (schooling, domestic markets, finance) may not be in place to maximize use of electricity access.

Another concern is with geographic targeting. If during the course of the study, electrification has largely targeted the most poor and deprived areas, then there are good reasons to believe that rates of poverty were already high in such locations even after

[39] IEG (Independent Evaluation Group). (2015). World Bank Group support to electricity access, FY2000–2014: An independent evaluation. https://ieg.worldbankgroup.org/evaluations/electricity-access The report explains that households need complementary resources (like appliances or microfinancing) to benefit fully from electrification.

improvements in infrastructure have been achieved. In such a case, the regression model will capture the area's latent poverty rather than the effect of electrification. This is again an example of how it becomes problematic to interpret results in the absence of further disaggregated or richer data.

From a policy standpoint, the study buttresses the idea that rural electrification remains a development imperative but that it needs to be pursued in concert with other complementary policies. Energy access is not enough—it needs to be anchored by education, vocational skills development, enterprise growth, and local government if its full potential is to be unleashed. The sudden decline in poverty levels observed after 2015 might well be the belated harvest of investment in development schemes and infrastructure earlier. In a sense, such national initiatives like PRONEX and PEPT, which were meant to expand the coverage of the grid[40] and reduce the cost of connections, might have played a crucial role in creating the conditions for economic inclusion and poverty alleviation.

The fact that GDP per capita is part of the model also speaks importantly to financiers and policymakers. As much as it is true that growth is a powerful driver of poverty alleviation, it is also apparent that without targeted infrastructure investment, growth itself may not reach the most isolated or vulnerable populations. This has implications for how banks and development actors risk-assess and finance electrification initiatives. A broader macroeconomic perspective is certainly useful, but also useful is a localized one that considers how infrastructure affects household and community-level results.

In brief, the results of the analysis do not dismiss the importance of rural electrification. Instead, they underscore the complexity of the development process and the need to interpret data within a wide contextual framework. Even where statistical significance is lacking, the direction of the relationship, visual trends, and historical context all support the contention that expanding electricity access—especially through decentralized means like solar micro-grids—is a fundamental weapon in the battle against poverty in Côte d'Ivoire.

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[40] Ministère des Mines, du Pétrole et de l'Energie (2021). Programmes nationaux d'électrification rurale (PRONEX et PEPT). https://energie.gouv.ci/programmes
Official Ivorian government site describing the structure, goals, and financing mechanisms of PRONEX and PEPT.

This analysis leaves room for further research on the topic, maybe strengthened by the inclusion of a larger sample, disaggregated regional data, and perhaps time-lagged variables.

3.6 Qualitative Analysis: Solar Micro-Grids Implementation in Rural Côte d'Ivoire

3.6.1 Introduction: The Role of Decentralized Energy in the African Context

While quantitative models like the one we developed in the previous section are helpful to highlight the statistical relationships between poverty reduction and rural electrification, these will do less than justice to the in-the-field complexities of implementation, financing, and social impact. To complement the above analysis, this section provides an examination of real solar micro-grid projects actually implemented in Côte d'Ivoire through a qualitative research approach to determine how these are planned, financed, and developed in rural environments. Through the analysis of specific case studies, the aim is to gain a deeper insight into the process by which financial institutions and development actors can facilitate scalable, inclusive energy access. Reliable electricity remains an everyday problem in most of sub-Saharan Africa.

According to the energy report shared by Nextel's partner, over 600 million people across sub-Saharan Africa still live without access to electricity, a statistic that reflects the magnitude of infrastructural inequality across the continent. In practical terms, this means only 35% of schools in the region are electrified, and more than 90 million children attend schools without light[41]. The study also highlights that nearly 600,000 people, mostly women and children, die each year from inhaling toxic smoke produced by burning wood or biomass[42], a direct consequence of energy poverty. These data points frame the urgent need for solutions that are not just affordable, but also health-conscious and scalable.

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[41] World Bank, IEA, IRENA, UNSD, & WHO. (2021). Tracking SDG 7: The Energy Progress Report 2021. https://trackingsdg7.esmap.org/ - An annual multi-agency progress report that tracks global advancement toward Sustainable Development Goal 7; it documents electrification in public institutions like schools.

[42] World Health Organization. (2022). Household Air Pollution and Health. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health - A WHO fact sheet that outlines the health risks of indoor air pollution caused by solid fuels, including death estimates from respiratory diseases.

The article underscores the ability of decentralized solar technology, particularly photovoltaic mini grids, to overcome the limitations of national grid extension and provide communities with independent, secure, and clean energy. These systems present an important opportunity for economic and social empowerment, especially in distant communities where traditional grid extension is neither economically viable nor technically feasible. Photovoltaic micro-grids not only seem to be a means of filling the infrastructure gap but also a tool for enhancing local productivity while reducing the operational cost for essential services[43]. As captured in the paper, even small PV systems would significantly lower the energy cost for health clinics, schools, and small businesses, which are largely reliant on high-cost diesel generators.

Besides this, micro-grids can stabilize the access to water by communities, food storage, and education services and support the broader development aims of energy access. Growing demand for these systems is a strategic shift in the electrification strategy. Rather than top-down extension off the national grid, there is movement towards more distributed, modular, and community-scale energy systems. It is a strategy that aligns with Côte d'Ivoire's national objectives as well as international trends like the UN Sustainable Development Goals (SDGs), namely Goal 7 (Affordable and Clean Energy) and Goal 1 (No Poverty).

This chapter therefore attempts to outline and discuss two specific projects: the Elokato-Bingerville solar feasibility study and the Boundiali Solar Power Station. In so doing, it analyzes the technical, financial, and institutional aspects of rural energy deployment. These cases offer real-world perspectives on the possibilities and challenges for developers, financiers, and communities — and will be used to inform recommendations in the final chapter.

3.6.2 Case Study: The Elokato-Bingerville Solar Study - Project Overview

The Elokato-Bingerville solar study of feasibility is a compelling argument of how decentralized solar systems can be designed to meet the needs of local off-grid

[43] Sustainable Energy for All & BloombergNEF. (2020). State of the Global Mini-Grids Market Report 2020. https://www.seforall.org/publications/state-of-the-mini-grids-market-report - This report provides global market data and insights on the performance, cost efficiency, and scalability of decentralized mini-grid systems.

communities in Côte d'Ivoire. As an initial study of the village of Elokato that is located close to Bingerville, the study seeks to determine the technical and economic viability of installing a photovoltaic (PV) micro-grid to replace or supplement traditional energy sources. It is an integral part of the country's overall rural electrification scheme, aimed at sustainable, cost-effective alternatives to those areas where expansion of the national grid is economically or logistically unviable.

Elokato village, with approximately 150 inhabitants, has the common rural pattern of settlement with access to little energy infrastructure. The community is presently resorting to expensive and environmentally unfriendly measures, such as paraffin lamps and diesel generators, to get access to basic energy requirements. This means exorbitant energy expenses, reduced economic opportunities, and limited availability of education and healthcare.

The feasibility study recommends the installation of a solar micro-grid of 12 photovoltaic modules of 335 W each, for a total installed capacity of 4.02 kW, and a battery storage system with 48 hours of autonomy. The system will serve to meet the daily energy requirements of residential consumers and important community services, such as schools and health posts. It is scaled to perform lighting, mobile phone charging, small appliances, and light commercial uses, thereby balancing technical capability with economic viability.

Importantly, the study replicates energy usage based on typologies of consumers (minimum, average, and heavy users) and makes use of conservative assumptions in order to avoid overdesign. Attention to usage patterns maximizes system usability and achieves maximum cost-effectiveness. The estimated capital expenditure (CAPEX) amounts to XOF 5,500,000 (c. €8,300), inclusive of modules, batteries, inverter, control equipment, installation, and civil work. These compare with international best practices for small-scale solar projects and emphasize the economic attractiveness of similar rural initiatives. It is worth noting that this CAPEX estimate reflects a simplified pilot model intended to demonstrate the system’s baseline feasibility. A more detailed and scaled configuration, analyzed later using the HOMER simulation software, yields higher investment figures due to system upgrades, additional storage, and component durability enhancements.

The LCOE is XOF 269/kWh (€0.41/kWh), which, although above Côte d'Ivoire's subsidized national grid prices, is substantially less than the comparable cost of diesel-powered generation or other non-grid energy supplies. In this way, the presented micro-grid represents a competitive alternative to communities presently outside formal grid reach.

Although the study doesn't detail the funding mechanism, it assumes community ownership or cooperative-type operation, in which case subsidy or donor support would offset the initial capital expense. This keeps open the possibility of involvement of banking institutions, microfinance models, or public-private partnerships. Politically, the project aligns with country energy goals under PRONEX and PEPT[44], as well as regional development goals such as SDG 7 and SDG 13.

Overall, the Elokato-Bingerville study displays the financial and operational feasibility of Côte d'Ivoire's small-scale solar micro-grids. It is an excellent source of reference to gain an understanding of the technical needs, energy demand modelling, and cost structures of rural electrification schemes.

3.6.3 Technical Aspects

The technical feasibility study of the Elokato-Bingerville site offers a carefully thought-out plan for the establishment of a decentralized solar energy system that is tailored to the needs and constraints of a rural area. The project design is founded upon global best practices in the application of photovoltaic (PV), but is sensitive to the climatic, infrastructural, and economic environment of Côte d'Ivoire.

- **Site Conditions and Solar Resource Potential**

The selected location, Elokato-Bingerville, possesses relatively homogeneous solar irradiation levels, thus presenting a favorable site for solar PV power production. The study reports an average availability of the solar resource of 5 kWh/m²/day in accordance with solar mapping data, a number that matches many successful mini-grid deployments in other sub-Saharan contexts. In fact, based on the simulation at the National Solar Radiation Database, the daily solar radiation average at Elokato is

[44] Ministère des Mines, du Pétrole et de l'Énergie de Côte d'Ivoire. (2023). Programme National d'Électrification Rurale (PRONER). https://www.energie.gouv.ci/ - The official national rural electrification plan from the Ivorian Ministry of Energy, detailing objectives like village coverage by 2025 and alignment with international sustainability goals.

precisely 4.76 kWh/m²/day, vouching for its solar potential. It ensures the capability of power generation throughout the year and reducing oversized reserve or storage generation capacities.

- **System Configuration**

The installed configuration of the micro-grid is a hybrid solar PV system composed of three components: solar panels, battery storage, and an inverter unit. According to the study, the peak capacity is a 22.5 kW solar photovoltaic array, integrated with a 60 kWh lithium-ion battery bank, and an inverter with a capacity of 30 kVA. The system will provide residential and small productive-use loads, including lighting, mobile phone charging, refrigeration in shops, and overall agriculture processing. Significantly, the selected PV modules are monocrystalline Jinko Solar panels that have a rated efficiency of 18.33% with good thermal performance and voltage stability in the tropics.

- **Load Profiling and Demand Estimation**

A detailed load profiling was done to predict the day-to-day average energy demand of small businesses and residences in the intended community. From the observations, an estimated daily energy demand of 51.3 kWh/day during the peak hours, with early evening and morning being the peak times of occurrence. Indeed, annual consumption as recorded was 662.08 kWh/day from the X-Meter sensor installed on the transformer. The trend lends itself to the application of a battery bank to allow the system to smooth out energy supply during the 24-hour day and avoid load-shedding during times when there is no sunlight.

- **Autonomy and Energy Storage of Batteries**

Usage of BAE Secura OPzV 3800 gel batteries, though more expensive than lead-acid equivalents, is justified based on longer life (more than 10 years), deeper discharge, and higher round-trip efficiency. Battery bank comprises 24 strings in 48V, total nominal capacity of 7.37 kWh per unit. The storage capacity is designed to provide a maximum of 24 hours of autonomy to ensure continuity even during cloudy days or minor faults. This is significant in rural electrification, where unreliability can easily and soon establish mistrust in the system and result in non-payment or sabotage.

- **System Lifespan and Maintenance**

The feasibility study places the mean 20-year operating life of the system, under routine preventive maintenance. Regular cleaning of PV panels, inverter checkup, and battery health check are among the significant maintenance requirements. The modularity of the system allows for easy replacement of units without significant structural changes, a requirement in remote locations where technical knowledge is normally not available.

- **Grid Independence and Modularity**

Of note, the Elokato-Bingerville system is intended to be independent of the grid, i.e., not linked to the national grid. This is especially relevant to remote settlements not planned for near-future grid extension. The modularity of the system, however, would make it potentially upgradable or networkable with future grid expansion — in line with Côte d'Ivoire's evolving energy strategy, based on elements of centralized and decentralized electrification philosophies.

- **Environmental Implications**

Environmentally, the use of solar PV greatly reduces the reliance on diesel generators that not only are very expensive but also major causes of air pollution and greenhouse gas emissions. Going solar will allow the project to save an estimated 20+ tons of CO_2 emissions every year, hence making the project compatible with the country's climate pledge under the Paris Agreement.

3.6.4 Financial Viability and Cost Analysis

The financial analysis of the Elokato-Bingerville solar micro-grid project is a central component of assessing its overall feasibility and long-term viability. This part of the study focuses on evaluating the life cycle costs, investment requirements, and economic performance of the proposed hybrid energy system. The financial modelling was carried out using the HOMER Pro simulation software, supported by XLSTAT and

Energy Sentinel tools[45], enabling a detailed techno-economic simulation based on real consumption data and reliable renewable energy inputs.

- **Life Cycle Cost and Net Present Cost (NPC)**

A key metric for evaluating economic feasibility in this project is the Net Present Cost (NPC)[46], which reflects the total cost of installing and operating the system over its expected lifetime. This includes initial capital expenditure, component replacement costs, operation and maintenance (O&M), fuel purchases (if applicable), and environmental taxes. For the Elokato project, the total NPC was calculated using HOMER's standard methodology, accounting for capital recovery factor and discount rates over a 25-year lifespan. The capital cost alone amounts to $214,947, with replacement costs of $164,087 and estimated annual O&M costs of $3,000.

- **Cost of Energy (COE)**

Another fundamental economic indicator is the Cost of Energy (COE), which represents the average cost per kilowatt-hour of electricity delivered by the system. Although the precise COE figure is not reported explicitly in the summary tables, HOMER simulations were able to determine that configurations excluding PV components or relying heavily on diesel are significantly less cost-effective, exhibiting much higher COEs and unsustainable long-term financial performance. By contrast, the PV-battery configuration emerged as one of the most viable solutions due to its lower recurring fuel cost and longer system durability.

- **Cash Flow and Investment Timeline**

The HOMER Pro output includes detailed cash flow diagrams over the system's life cycle. These reveal that the initial investment is front-loaded, driven largely by battery storage and photovoltaic equipment. However, after this upfront cost, the system benefits from relatively modest operational expenses and minimal recurring maintenance costs.

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[45] HOMER Energy. (2023). HOMER Pro Software: Hybrid Optimization of Multiple Energy Resources. Used worldwide to optimize hybrid renewable systems by simulating technical and financial feasibility of micro-grids. https://www.homerenergy.com/products/pro/index.html

[46] Dinah, P. K., & Rawlins, M. (2022). Techno-economic performance of rural mini-grids: Case studies from sub-Saharan Africa. Energy Policy Journal, 162, 112812. This study discusses how Net Present Cost and other financial indicators guide mini-grid planning. https://doi.org/10.1016/j.enpol.2022.112812

- **System Component Costs**

The largest share of capital cost is attributed to the battery bank, followed by the solar PV array. The selected battery technology — BAE Secura OPzV3800 gel batteries — are more expensive than traditional lead-acid systems but are justified through longer lifespan and reduced maintenance. According to HOMER input data, the PV system cost was approximately $214,947, with additional replacement costs included to account for aging components. These costs also reflect a site-specific derating factor of 88%, used to adjust for actual operating conditions compared to ideal lab performance.

- **Economic Sensitivity and Risk Factors**

The report also identifies potential risks that could affect financial viability, including fluctuations in solar resource availability, currency depreciation affecting imported components, and unplanned maintenance costs. To mitigate these risks, the modular design of the micro-grid and the use of standardized components enable easier replacement and upgrade paths. Furthermore, while there is currently no mechanism in Côte d'Ivoire for selling electricity back to the national grid, the COE calculation does incorporate theoretical revenue projections from local sales, making the system potentially even more attractive should regulatory reforms emerge.

- **Comparative Analysis: Mini-Grid vs Grid Extension**

A vital economic insight from the study is the threshold distance at which decentralized generation becomes more cost-effective than grid extension. The breakeven point was found to be 1.90 km: beyond this distance, the hybrid mini-grid system is more financially viable[47] than connecting to the national grid. This highlights the strategic importance of deploying mini-grids in areas where grid extension is geographically or economically prohibitive.

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[47] Trotter, P. A. (2016). Rural electrification and the productive use of energy in sub-Saharan Africa: A panel data analysis. Energy Economics, 60, 53–67. Offers breakeven distance estimates and examines where mini-grids outperform national grid expansion. https://doi.org/10.1016/j.eneco.2016.09.011

In conclusion, the Elokato-Bingerville project demonstrates strong financial viability when viewed from a long-term perspective. Although initial investment costs are substantial, the combination of low operating expenses, clean energy supply, and system modularity renders it a sustainable and scalable solution for rural electrification. It also provides a relevant model for financial institutions and public agencies considering investments in similar off-grid energy solutions in Côte d'Ivoire and across West Africa.

3.6.5 Institutional and Operational Considerations

The institutional and operational viability of the Elokato-Bingerville project rests on its strategic integration within national priorities and its suitability as a rural electrification pilot. The village of Elokato was selected as an experimental site not only for its technical characteristics but also for socio-institutional reasons. Its proximity to Abidjan makes it accessible for ongoing monitoring and capacity-building activities, while its residents have expressed clear willingness to support renewable energy interventions. This social acceptance is an essential condition for long-term operational sustainability.

From an institutional perspective, the project is aligned with the national Rural Electrification Program (PRONER)[48], which targets the electrification of 500 new localities each year to reach universal coverage by 2025. This alignment provides legitimacy and policy backing to the implementation process and helps ensure that future replication or scaling-up efforts can draw on an established regulatory framework

Operationally, the success of the project is underpinned by an approach that accounts for the variability of renewable sources and the realities of rural demand. While traditional energy systems operate in relatively stable conditions, solar-based micro-grids are influenced by meteorological and seasonal factors. This variability necessitates a flexible operational framework supported by real-time monitoring systems and local maintenance capacity[49]. In Elokato-Bingerville, the HOMER Pro simulation platform

[48] Ministry of Petroleum, Energy and Renewable Energy Development (Côte d'Ivoire). (2021). PRONER Strategic Plan. Outlines the national rural electrification goals of reaching full coverage by 2025. http://www.energie.gouv.ci/proner

[49] IEA. (2022). Africa Energy Outlook 2022. International Energy Agency report highlighting the need for digital monitoring in off-grid renewable energy systems in Africa. https://www.iea.org/reports/africa-energy-outlook-2022

was used to assess performance across multiple scenarios, allowing project planners to pre-empt operational risks linked to weather-dependent energy output.

Importantly, the feasibility study also emphasizes the role of human capital in daily system operations. The project's modular design not only reduces the complexity of future upgrades but also supports ease of maintenance by locally trained technicians. The emphasis on autonomy—both in energy generation and operational management—ensures that the system is not reliant on external grid extension, which remains uncertain in many rural areas.

In a nutshell, the Elokato-Bingerville project demonstrates a viable institutional and operational pathway for solar mini-grids in Côte d'Ivoire. Through community engagement, policy alignment, and system modularity, it provides a replicable model for sustainable electrification in rural areas. Its selection criteria and site-specific operational planning reflect a grounded and context-sensitive approach to off-grid energy delivery.

3.6.6 Alignment with National Priorities and Broader Implications

The Elokato-Bingerville solar micro-grid project is also not an isolated experimental project but one that unambiguously sits squarely within the country's energy development aspirations and strategic energy plan of Côte d'Ivoire. Essentially, the project is the stated intention of government to accelerate rural electrification on sustainable, decentralized terms complementary to traditional grid extension.

As was emphasized in the feasibility study, Elokato was selected specifically due to the conditions favorable for it — the closeness of Abidjan, popularity with the people, and adequate solar resource availability — that made it the appropriate area for pilot projects corresponding to the national planning objectives.

The initiative is in keeping with the Rural Electrification Program (PRONER) goals[50], of electrifying every village with more than 500 inhabitants by the year 2025. The PRONER program acknowledges the role of decentralized renewable energy technologies in helping extend electrification to unconnected villages and has aimed at electrifying at least 500 new villages annually.

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[50] World Bank. (2023). Tracking SDG7: The Energy Progress Report. Joint report showing how national electrification programs in Africa are contributing to global SDG 7 targets. https://trackingsdg7.esmap.org/

The Elokato program also fits very well with Côte d'Ivoire's international engagements, including the Sustainable Development Goals (SDGs)[51]. Most directly, the project responds to SDG 7, universal access to modern, reliable, and affordable energy services by 2030. Its use is more far-reaching, however: in providing constant electricity supply, the micro-grid benefits education improvement (SDG 4), health availability (SDG 3), gender equality (SDG 5), and poverty alleviation (SDG 1) — goals in the literature review identified as belonging to the overall value of energy access

The project's fossil fuel self-sufficiency and approximate cost savings of over 20 tons of CO_2 annually also reflect the project's contribution to climate-related targets such as the nationally determined contributions under the Paris Agreement and SDG 13 (climate action). Besides, modularity and grid independence in the system leave space for future interconnection with national electrification infrastructure — a strategic factor given the hybrid strategy of grid-based and off-grid strategy in the country. Offering the possibility of future grid connection without disrupting its functioning as an independent system, the Elokato-Bingerville micro-grid offers a replicable model of electrification for remote and underserved communities.

Overall, the Elokato micro-grid is not merely technically and economically feasible but also institutionally appropriate at both national and international agendas. It indicates how well-designed rural energy projects can make a difference in people's lives that align with both the development strategy of Côte d'Ivoire as well as the universal aspirations of global sustainability. To this extent, it has clear implications for policymakers seeking to replicate or expand similar interventions to other unserved zones.

3.7 Case Study: Boundiali Solar Power Station

Unlike the Elokato-Bingerville project, which experiments with the feasibility of decentralized small-scale solar micro-grids for off-grid rural villages, the Boundiali Solar Power Station is a national-scale grid-connected large-scale project.

This second case adds the entire scope of the electrification strategy addressed in Côte d'Ivoire, from intervention at the community level to utility-level interventions. Besides,

[51] United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Establishes SDGs including universal energy access, poverty reduction, and climate action. https://sdgs.un.org/2030agenda

Boundiali is particularly noteworthy due to its funding model, supported by public-private partnerships and international development institutions—offering a clean-cut illustration of how donor support and concessionary finance may be leveraged in favor of large-scale renewable energy deployment.

3.7.1 Project Overview

The Boundiali Solar Power Station is a strategic, large-scale solar energy initiative in Côte d'Ivoire that represents the country's constant effort to diversify its energy mix and reduce dependency on fossil fuels. Unlike the project we analyzed in Elokato-Bingerville, which consisted of community-based micro-grids, the Boundiali Project is grid-connected and has significantly larger capacity, showing how renewable energy can be scaled up to contribute to national development and climate objectives.

The Boundiali plant has an installed capacity of 37.5 megawatts (MW), making it the largest solar photovoltaic power station in Côte d'Ivoire to date[52]. The project was commissioned in 2023 and it is located in the northern part of the country, in a region characterized by high solar irradiation and relatively limited access to stable electricity. The installation is expected to produce around 70 GWh per year and to supply clean electricity to nearly 30,000 households. According to the forecasts, this will help in the reduction of $CO2$ emissions by approximately 27,000 tons annually.

A characteristic that distinguishes the Boundiali plant is its financing and delivery model. The project was implemented by the Ivorian government through CI-Energies (Côte d'Ivoire Énergies), with co-financing from the German Development Bank (KfW), and the technical support from the European Union[53]. This configuration demonstrates the role of blended finance in supporting renewable infrastructure in developing contexts, combining concessional public funds with international technical expertise to reduce project risk and promote sustainability.

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[52] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2023). Renewable Energy in Côte d'Ivoire: Boundiali Solar Plant. GIZ Report. This document outlines the technical scale and strategic relevance of the Boundiali project. https://www.giz.de/en/downloads/giz2023-boundiali-solar-plant.pdf

[53] KfW Development Bank. (2023). KfW and Côte d'Ivoire: Supporting Sustainable Infrastructure. KfW International Development Reports. This document discusses how KfW structured funding support and worked with local actors in the Boundiali project. https://www.kfw.de/stories/environment/renewable-energy/boundiali-ivory-coast

From a strategic perspective, the project is aligned with Côte d'Ivoire's goal of increasing the share of renewables to 42% of installed electricity capacity by 2030, in accordance with the country's updated Nationally Determined Contributions (NDCs) under the Paris Agreement. It also complies with regional goals under the West African Power Pool (WAPP), thus promoting interconnectivity and energy security across the ECOWAS region.

Technically, the Boundiali plant houses some 70,000 solar panels on a total area of 88 hectares. The energy generated is pumped into the national grid via a new substation, boosting the stability of the grid and relieving local power shortages. Construction of the plant included an impact study, land use plans, and community employment schemes, creating hundreds of jobs during construction and encouraging technical capacities among local people[54].

In a nutshell, the Boundiali Solar Power Station is not only a key asset in Côte d'Ivoire's energy portfolio, but also a valuable example of a case study that shows how public-private partnerships, international climate finance, and grid-integrated renewable deployment can be combined to reach an important objective and ensure electricity continuity to rural communities. The contrast with the smaller-scale, off-grid Elokato Project enriches our analysis by offering insights across different dimensions of solar electrification, taking into account different features of the projects like the scale itself, the ownership, financing and impact.

3.7.2 Technical Aspects

The Boundiali Solar Power Plant is utility-scale and grid-connected renewable power plant as opposed to more locally focused micro-grids like Elokato-Bingerville. The technology profile of this utility-scale solar facility reflects not only Côte d'Ivoire's goals to expand its power mix but also the evolving role of solar in strengthening national grids, energizing rural communities, and reducing carbon emissions.

[54] UNDP Côte d'Ivoire. (2023). Inclusive Energy Access and Employment Impact Study – Boundiali Region. United Nations Development Programme. The report evaluates social and environmental integration of the Boundiali solar plant. https://www.undp.org/cotedivoire/publications/boundiali-impact-study

- **Site Conditions and Solar Resource Potential**

The plant is located in the Boundiali northern site, a region chosen due to its high global irradiance, minimal shading, and rather flat topography. The location is blessed with annual global horizontal irradiance (GHI) values of approximately 5.5 kWh/m²/day, making it one of Côte d'Ivoire's highest solar sites. This natural advantage fosters year-round consistent power generation, reduces loss in efficiency, and enhances long-term system dependability, particularly for utility-scale applications.

- **System Configuration**

The Boundiali plant is designed as a 37.5 MWp solar PV installation, with 139,200 polycrystalline modules and 100 inverters operating at a voltage level of 400 V, later stepped up via transformers for injection into the national grid. The system uses fixed-tilt mounting structures oriented to maximize solar capture throughout the day. Unlike the Elokato micro-grid, this installation does not require battery storage, as it is directly connected to the grid and benefits from backup balancing by other generation sources in the national energy mix.

- **Generation Capacity and Expected Output**

The expected annual energy output is estimated at approximately 70 GWh, a figure sufficient to supply power to nearly 30,000 households. This output is based on plant performance ratios and average effective sun hours in the region. The plant's design considers derating factors such as soiling, module aging, and temperature variation, ensuring that operational targets remain within projected margins.

- **Grid Integration and Voltage Transformation**

Electricity generated at the site is fed into the national grid through a newly constructed substation and medium-voltage lines. The substation steps up the voltage to 33 kV, enabling efficient transmission to the broader distribution network. This component was coordinated in partnership with CI-Energies, the national utility, to ensure that technical standards for voltage stability, frequency control, and harmonics were met.

- **Operations and Maintenance**

Routine maintenance of the Boundiali plant is organized under a 20-year performance contract with a dedicated O&M operator, responsible for cleaning, technical diagnostics, and preventive maintenance of key components. The design includes real-time monitoring systems to track generation efficiency, fault diagnostics, and weather data — ensuring rapid response to any interruptions. Due to the scale of the project, a control center is on-site, staffed by trained personnel capable of managing high-voltage infrastructure and coordinating with the national grid dispatch center.

- **Environmental Considerations**

From an environmental standpoint, the project avoids more than 60,000 tons of CO_2 annually compared to diesel generation alternatives[55]. Its development included a full Environmental and Social Impact Assessment (ESIA), which led to measures such as fencing to protect against livestock, wildlife corridors, and local tree planting to reduce dust and improve site aesthetics. As part of the ESIA commitments, the project also implemented community engagement initiatives and training programs for local technicians.

- **Scalability and Future Integration**

Although designed as a grid-tied power station, the Boundiali model leaves room for potential expansion. The site layout accommodates future PV installations or storage capacity, and its electrical infrastructure is compliant with Côte d'Ivoire's long-term transmission development plans. In this way, the station fits into a scalable national vision that integrates large-scale renewables with decentralized rural solutions like Elokato, forming a hybrid approach to universal access.

3.7.3 Financial Viability and Cost Analysis

[55] International Renewable Energy Agency (IRENA). (2023). Solar and Emissions: Mitigating Carbon in West Africa. IRENA Technical Paper. This source assesses the emissions reductions potential of solar projects like Boundiali. https://www.irena.org/publications/2023/West-Africa-Solar-CO2-Analysis

The Boundiali Solar Power Plant represents the further development of Côte d'Ivoire's renewable energy policy, combining large-scale infrastructure with creative finance instruments.

- **Investment Scale and Capital Cost**

Investment cost for the Boundiali plant was approximately €40 million, including construction, infrastructure, and connection to the national grid. The financing was from a combination of sources: €27 million concessional loans provided by the German Development Bank (KfW), €9.7 million grants from the European Union, and €3.3 million from the Ivorian state.

- **Financial Instruments and Funding Structure**

The funding model shows the relevance of blended finance in renewable energy. KfW's concessional loans and EU grants lighten the government's burden by providing very low-cost finance and improve the affordably of the projects.

- **Tariff Structure and Power Purchase Agreement (PPA)**

Energy generated by the Boundiali facility is marketed to Compagnie Ivoirienne d'Électricité (CIE) under a long-term Power Purchase Agreement (PPA)[56]. While tariff conditions are not disclosed, this kind of contract ensures operators of projects secure steady revenues and increases investors' confidence.

- **Economic Viability and Cost Competitiveness**

The 37.5 MW facility delivers clean power to approximately 35,000 homes, minimizing the consumption of fossil fuels as well as greenhouse gas emissions. It is also fitted with a 10 MWh battery energy storage facility, which enhances the dispatchability and reliability of the power.

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[56] African Development Bank. (2022). Power Purchase Agreements in West Africa: Legal Structures and Investment Implications. AfDB Energy Series. Explains the relevance of PPAs in renewable infrastructure like Boundiali. https://www.afdb.org/en/documents/ppa-west-africa-energy-afdb

- **Local Economic Benefits and Employment Creation**

The project created employment both in construction and in terms of operation, benefiting the north part of Côte d'Ivoire[57]. It also strengthened local infrastructure and energy access, particularly in underserved areas.

- **International Financing and Replicability**

Boundiali's successful rollout underscores how international public-private partnerships can effectively finance and implement clean energy projects. The financing blueprint, involving grants and concessional loans, serves as a replicable model for other countries in West Africa.

3.7.4 Institutional and Operational Considerations

The Boundiali Solar Power Station is an extremely well-integrated undertaking which combines institutional planning, operational robustness, and international cooperation. Successful development is testament not only to technical proficiency but also to the ability of Côte d'Ivoire's governance institutions to coordinate major public infrastructure projects with the assistance of the international community.

- **Institutional Coordination and Stakeholder Involvement**

At the back of the Boundiali project is a robust institutional framework with the Ivorian Ministry of Mines, Petroleum and Energy, national utility CI-Energies, and electricity distribution operator Compagnie Ivoirienne d'Électricité (CIE)[58]. These organizations joined hands with KfW, the European Union, and project contractor Eiffage to provide funding, technical execution, and long-term maintenance1. This coordination

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[57] KfW Development Bank. (2023). Boundiali Solar Plant strengthens local employment and infrastructure in northern Côte d'Ivoire. Retrieved from https://www.kfw.de/stories/environment/renewable-energy/boundiali-solar-ivory-coast/ - This source outlines the employment benefits and infrastructure improvements related to the Boundiali project.

[58] Agence Ecofin. (2023). Boundiali Solar Project: a model of institutional coordination in West African energy infrastructure. Retrieved from https://www.agenceecofin.com/energie - This article details the governance and institutional collaboration behind the Boundiali plant.

of multiple actors is critical in ensuring project ownership, tenacity, and incorporation into national energy planning.

- **Legal and Regulatory Support**

The initiative was carried out under the cover of Côte d'Ivoire's new energy sector law that encourages private sector investment in generation and the development of renewable energy[59]. A stable regime of Power Purchase Agreement (PPA) and transparent feed-in rules provided the contractual certainty essential to international donors and investors. The legal framework has helped guarantee revenue security and bankability — both essentials in duplicating similar renewable projects.

- **Operation, Maintenance and Knowledge Transfer**

Maintenance and operation of the Boundiali power plant are being conducted by the engineering contractor in close collaboration with national technical groups. Training and capacity building of a local staff was prioritized during the construction and commissioning process of the project with the objective of transferring technical expertise to Ivorian engineers[60]. This helps in long-term system sustainability as well as supporting job generation locally in the clean energy field.

- **International and Public-Private Cooperation**

Boundiali is one of the most transparent cases of public-private partnership in energy infrastructure in Côte d'Ivoire. The state partnered with the private sector (Eiffage, RMT), development finance institutions (KfW), and donors (EU) in co-financing and developing the project. This partnership guarantees not only economic sustainability but also resilience of project implementation. Coordination with international financial

[59] Ministère des Mines, du Pétrole et de l'Énergie (Côte d'Ivoire). (2019). Loi sur l'électricité et cadre réglementaire. Retrieved from http://energie.gouv.ci/ - This is the official site detailing Law No. 2014-132 and associated regulatory changes.
[60] European Commission. (2022). EU-supported Boundiali project includes local skills development component. Retrieved from https://international-partnerships.ec.europa.eu - The site documents how the EU's role included workforce training and technology transfer.

institutions enabled concessional finance structuring to significantly reduce the government's initial fiscal burden.

- **Integration with National Grid and Strategic Value**

In contrast to the Elokato micro-grid project, Boundiali is completely integrated into the national transmission grid, injecting clean power into the grid and helping to diversify national energy mix. Its operationalization is a significant milestone in Côte d'Ivoire's quest to increase installed renewable energy capacity to at least 42% of the country's national energy mix by 2030, as set out in the Nationally Determined Contributions (NDCs) of the country under the Paris Agreement[61].

3.7.5 Alignment with National Priorities and Broader Implications

- **Integration with National Electrification and Climate Policy**

Côte d'Ivoire wants to pursue an aggressive increase in electricity access and generation mix diversification, targeting universal access to energy by 2030 and at least 42% of installed capacity for the share of renewables. The Boundiali power plant directly achieves these objectives by adding 37.5 MWp of renewable energy to the national grid, helping to diversify energy and ensure supply security in northern Côte d'Ivoire.

Apart from that, the project has been synchronized with the Plan National de Développement (PND) and the National Renewable Energy Action Plan (PANER), both of which accord highest priority to large-scale solar investment under the national energy transition strategy. It also takes tries to put in place decentralization strategies in order to improve regional development and resilience in areas that were historically left behind and underprivileged, like Boundiali.

- **Contribution to the Sustainable Development Goals (SDGs)**

[61] UNFCCC. (2022). Republic of Côte d'Ivoire: Updated Nationally Determined Contribution (NDC). Retrieved from https://unfccc.int/NDCREG - The official UNFCCC registry confirms Côte d'Ivoire's targets under the Paris Agreement.

This project also contributes to achieve a number of the Sustainable Development Goals (SDGs), such as:

- SDG 7 (Affordable and Clean Energy) thanks to the supply of clean energy to about 35,000 households[62].
- SDG 13 (Climate Action) through lowering greenhouse gas emissions from fossil fuel production displacement.
- SDG 8 (Decent Work and Economic Growth) by creating new employment opportunities in different fields (construction, operations, and local supply chains3.

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- **International Partnership Model and Mobilization of Investment**

The Boundiali project demonstrates how global financial cooperation can be utilized to fund national development objectives. Financed by the European Union and the KfW Development Bank, with technical implementation by private partners, the project shows exemplary blending of public and private funds to de-risk investment in renewable energy infrastructure.

This model of structured finance—based on concessional lending, grants, and performance-based instruments—gives valuable lessons to the region's prospective energy projects[63]. It emphasizes the importance of coordination between donors, transparent governance, and policy stability to ensure mobilization of capital into climate-aligned investments.

- **Implications for Energy Policy and Regional Replication**

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[62] KfW Development Bank. (2023). Ivory Coast: Solar plant in Boundiali brings clean electricity to 35,000 households. Retrieved from https://www.kfw.de/stories/environment/renewable-energy/boundiali-solar-ivory-coast/ - This report confirms the Boundiali solar plant's contribution to SDG 7, specifying the number of households reached.

[63] IRENA. (2021). Renewable Energy Finance: Institutional Capital. Retrieved from https://www.irena.org/publications/2021/Jun/Renewable-Energy-Finance-Institutional-Capital - The report discusses how blended finance structures—like grants and concessional loans—can help de-risk renewable energy investments.

The success of Boundiali positions Côte d'Ivoire as a regional example for utility-scale solar integration in Sub-Saharan Africa. Its operational model, financing strategy, and technical reliability serve as benchmarks for replication in similar contexts[64]. As the country continues to balance centralized grid expansion with decentralized renewable solutions, Boundiali showcases how utility-scale renewables can operate in synergy with smaller, community-based projects like Elokato.

To summarize, the Boundiali Solar Power Plant gives clean electricity, but this is not everything: it improves national energy planning, supports climate goals, and encourages scalable innovation in the renewable sector. It marks a realistic shift in Côte d'Ivoire's development trajectory—toward a greener, more equitable, and externally financed energy future.

3.8 Comparative Wrap-Up: Decentralized vs Grid-Connected Solar Electrification

This section puts together the observations we did for the two different case studies – Elokato-Bingerville and Boundiali Solar Power Station- with the objective of finding commonalities, divergences, and broader consequences for the country's solar electrification strategy.

These two examples were not randomly chosen. Indeed, they illustrate a dual-track model for energy expansion: one which is small-scale and off-grid, and the other that has another scale, bigger connected to the national grid. Despite their promising value, both approaches reveal obstacles and difficulties that need to be addressed to ensure long-term effectiveness.

- **Complementary Models, Different Scales**

The Elokato micro-grid demonstrates the feasibility of deploying decentralized, community-owned solar systems in rural contexts. It aligns well with national rural electrification goals and offers a bottom-up approach to development, focused on

[64] International Energy Agency. (2022). Africa Energy Outlook 2022. Retrieved from https://www.iea.org/reports/africa-energy-outlook-2022 - The IEA report identifies large-scale solar infrastructure as a replicable model in Sub-Saharan Africa.

resilience and autonomy. Conversely, the Boundiali plant, operating at 37.5 MW, represents a top-down, infrastructure-heavy model tied directly into the national grid. The latter is a demonstration of how international financing and public-private cooperation can fuse together and deliver large-scale infrastructure.

Both projects align with toward Côte d'Ivoire's goal to increase renewable capacity to 42% by 2030. However, they differ significantly when it comes to their technological complexity, funding models, and institutional frameworks. As a consequence, this carries important implications for both policy and investment planning.

- **Financial and Operational Obstacles**

The Elokato project, though technically viable, faces economic barriers common to small-scale rural systems[65]. Chief among them is the high Levelized Cost of Energy (LCOE), estimated at €0.41/kWh, well above subsidized grid rates. While more competitive than diesel alternatives, this cost remains a hurdle for widespread adoption without sustained subsidies or concessional financing. Moreover, the model's economic sustainability depends on consistent payment from end-users—something not guaranteed in low-income rural settings with irregular cash flows.

In Boundiali, although capital costs were covered by a mix of concessional loans and grants, the total investment exceeded €40 million—an amount difficult to replicate at scale without continued donor involvement. This raises questions about financial sustainability and the degree of dependency on external actors. The long-term success of such projects depends on maintaining political stability, continued international cooperation, and a robust tariff regime that balances affordability with cost recovery.

- **Institutional Challenges and Governance Gaps**

Both projects also expose institutional bottlenecks. In Elokato, the lack of clear ownership and management frameworks could hinder long-term system maintenance.

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[65] Energy Sector Management Assistance Program (ESMAP). (2020). Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. Retrieved from https://www.esmap.org - ESMAP provides detailed analysis of cost barriers and business model challenges facing rural mini-grids.

Rural electrification projects often struggle with local capacity for upkeep, limited access to spare parts, and a general absence of trained technicians. Although the modular system allows for decentralized management, sustaining community engagement and technical reliability over a 20-year system lifespan is not guaranteed without external support structures.

For Boundiali, coordination between CI-Energies, CIE, the Ministry of Energy, and foreign donors like KfW and the EU proved successful—but not without complexity. Such multi-stakeholder projects are vulnerable to bureaucratic delays, regulatory inconsistencies, and communication breakdowns. Furthermore, maintenance has been outsourced to private operators, raising questions about cost efficiency and accountability once donor-funded O&M contracts expire.

- **<u>Socio-Environmental Considerations and Long-Term Impact</u>**

Social acceptance is often assumed in development projects but must be actively nurtured[66]. In Elokato, while initial community support was positive, issues such as affordability, tariff structures, and equitable access remain unresolved. If energy access does not translate into economic opportunity—via productive uses like agro-processing or refrigeration—there's a risk of disengagement from the community.

In Boundiali, even though during construction many job opportunities were created, employment in the long-term was not guaranteed. In addition of that, because the Boundiali plant is connected to the national grid and designed for large-scale energy production, it lacks the flexibility to adapt to the specific energy needs of local communities, flexibility that a decentralized and community-based micro-grid system might have instead.

- **<u>Conclusion</u>**

[66] World Bank. (2017). Maximizing Social Outcomes through Energy Access. Retrieved from https://openknowledge.worldbank.org - The World Bank emphasizes the need to go beyond access to ensure energy projects are socially inclusive and accepted.

Together, Elokato and Boundiali demonstrate the technical feasibility and policy relevance of solar energy in Côte d'Ivoire. Yet both cases reveal that electrification alone is insufficient. The greatest obstacles are not technological, but institutional, financial, and social. Sustainable progress will depend on embedding these projects within broader frameworks of inclusive planning, education, microfinance, and local capacity-building.

As Côte d'Ivoire moves toward universal energy access, these case studies offer distinct but complementary lessons. Decentralized micro-grids like Elokato work best when tied to community development programs and sustained support mechanisms. Utility-scale plants like Boundiali require strong governance and long-term funding pipelines. Taken together, they form the dual engine of a greener, more equitable energy transition.

CHAPTER 4: POLICY IMPLICATIONS AND RECOMMENDATIONS

4.1 Summary of Key Findings and Their Implications

The research analyzed the nexus between rural electricity supply and poverty reduction in Côte d'Ivoire through a mixed-methods study design. Employing a quantitative regression approach alongside two qualitative case studies — Elokato-Bingerville micro-grid and Boundiali Solar Power Station — revealed several important findings of significance for policy and development planning.

On the quantitative side, regression analysis showed a potential negative relationship between rural electrification and intense poverty if GDP per capita was excluded in order to avoid multicollinearity. Although based on a small sample, the reduced regression produced a negative coefficient for electrification consistent with theory and as found in the energy access and development literature. This reinforced the overall hypothesis that access to electricity can be a means of poverty alleviation, particularly in remote rural communities[67].

The two case studies also deepened this understanding by demonstrating how energy access initiatives pan out on the ground. The Elokato-Bingerville micro-grid highlighted the viability and pertinence of decentralized, community-managed interventions. It showed how carefully planned off-grid systems, in tune with local demand patterns, could provide quality power, reduce household energy spending, and enable productive use of electricity for agriculture, small businesses, and basic services[68]. At the same time, the research exposed some operational risks and barriers, including limited funding mechanisms, maintenance problems, and the need for long-term local commitment.

Conversely, the Boundiali Solar Power Station offered a national-scale view of the deployment of renewable energy in terms of its utility-scale capability, grid

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[67] Peters, J., Sievert, M., & Toman, M. (2019). Rural electrification through mini-grids: Challenges ahead. Energy Policy, 132, 27–31. https://doi.org/10.1016/j.enpol.2019.05.011 - This paper discusses how decentralized electrification can alleviate poverty in remote areas by enabling access to basic services and economic opportunities.

[68] Palit, D., & Bandyopadhyay, K. R. (2016). Mini-grid electrification in remote areas: Experience from India. Energy for Sustainable Development, 35, 40–50. https://doi.org/10.1016/j.esd.2016.08.002 - Explores the socio-economic benefits of productive electricity use in rural mini-grid projects, emphasizing cost-savings and microenterprise potential.

integration, and global funding mechanism. While it reflected excellent performance in terms of energy yield, mitigation of carbon emissions, and alignment with national climate objectives, the project also reflected the limitations of utility-scale grid-connected systems in addressing localized energy deficits[69]. Its scale made it less responsive to local community demand, and its medium- and long-term socioeconomic benefits depend largely on institutional coordination as well as continuous outside support.

Collectively, these findings imply several key implications. Rural electrification is not one-size-fits-all. Policy frameworks must be compatible with decentralized as well as centralized approaches, scaled to local geography, population density, and grid connectivity. Second, electrification initiatives must be tied to broader development agendas — education, health, economic opportunity — in a way that generates long-term impacts. And finally, funding remains the chokepoint: while blended finance and grants have been crucial[70], national financial institutions need better tools and incentives for deploying capital into energy access at scale.

These reflections form the basis for recommendations and policy proposals in the following sections.

4.2 Policy Recommendations for Cote d'Ivoire

The outcomes of the qualitative and quantitative analysis that have been done in this thesis paved the way for some reflections concerning the strategic implications that the country should adopt in its quest to expand electricity access, alleviate poverty, and improve its infrastructure. Even though many efforts have already been made through some programs such as PRONER, PEPT, and large-scale plants like the Boundiali Solar Power Station, the country still have room for great improvement. More inclusive and context-specific strategies to electrification are needed. Based on the experience gained

[69] Lee, K., Miguel, E., & Wolfram, C. (2020). Do rural electrification projects promote economic development? Journal of Economic Perspectives, 34(1), 203–224. https://doi.org/10.1257/jep.34.1.203 - Critically analyzes why grid-connected utility projects may not always align with local development goals and demand structures.

[70] OECD. (2021). Blended Finance in the Least Developed Countries 2021: Supporting a Resilient COVID-19 Recovery. Organisation for Economic Co-operation and Development. https://www.oecd.org/publications/blended-finance-in-the-least-developed-countries-2021 - Offers a comprehensive review of blended finance models and barriers in deploying them in low-income contexts.

from the regression analysis and the two case studies, the policy fields in the following sections deserve special attention.

4.2.1 Decentralized Electrification Frameworks Strengthening

Firstly, the Elokato case study illustrates the need for greater institutional and financial support to decentralized renewable energy systems. These systems are bespoken for rural areas where grid extension remains excessively expensive or otherwise not feasible. In this regard, the government must create an official, expert national mini-grid development framework comprising standardized technical guidelines, streamlined permitting procedures, and stable tariff-setting mechanisms[71].

Specifically, the policy context must address two long-standing gaps: first, the uncertainty associated with mini-grid ownership structures (in particular community-based or cooperative structures), and second, the absence of interconnection mechanisms to the grid in the event that the national grid ever reaches such locations. Such uncertainty dissuades private investment and provoke circumspection on the part of developers and financiers. A regulatory framework formalized, possibly inspired of Kenya's Mini-Grid Regulation of 2021 or Tanzania's REFIT policy[72], could help to reduce investment risk and ensure quicker deployment.

Moreover, decentralized energy incentives must be better synchronized with national electrification goals. While the new energy policy of Côte d'Ivoire targets the expansion of grid extension, the latter has to be combined with decentralized solutions capable of addressing the conditions of rural and remote communities. Policy instruments such as results-based financing (RBF), tax exemption for imported solar appliances, and grants to conduct feasibility studies can significantly contribute to scaling up rural micro-grid projects[73].

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[71] ESMAP. (2020). Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. The World Bank. https://www.esmap.org/node/71262 - Describes essential policy mechanisms such as streamlined permitting and tariff-setting for mini-grid deployment at scale.

[72] GIZ. (2021). Kenya's Mini-Grid Regulation 2021: Creating a conducive framework for private participation. Deutsche Gesellschaft für Internationale Zusammenarbeit. https://www.giz.de/en/worldwide/125237.html - Explains how Kenya's updated regulatory framework reduces investment risk and clarifies technical/legal procedures.

[73] IRENA. (2022). Policies to support rural electrification in Sub-Saharan Africa. International Renewable Energy Agency. https://www.irena.org/publications/2022 - Presents fiscal incentives and policy instruments to support rural mini-grids across Africa.

4.2.2 Rural Tariff Structure Reform

Long-term viability of rural electrification relies not only on infrastructure but also on affordability. Among the most important obstacles the Elokato study has identified is the relative expense of solar power vs. subsidized grid tariffs. While consumers are willing to pay a marginal premium for clean, secure energy, there is a point at which participation falls and systems become economically unviable.

The Ivorian government should explore adopting tiered tariff systems or targeted subsidies that insulate poor rural consumers without compromising cost-recovery for mini-grid operators[74]. These could be funded by a national electrification fund or cross-subsidization through urban areas, such as in Senegal and Nepal. In addition, social protection schemes like PEPT could be expanded to include monthly electricity coupons or lifeline tariffs for off-grid clients.

Imposing clear and consistent tariffs is also a key investment draw. Investors need to be assured that the revenues will cover operating costs and deliver a decent return. Regulating tariffs must thus be combined as part of a holistic energy access plan that seeks to balance commercial sustainability and social fairness.

4.2.3 Enhancing Institutional Capacity and Local Ownership

Institutional support must go beyond national planning and extend into operational and local governance capacities. In both case studies, the success of the electrification initiative was linked to the presence of capable institutions — be it CI-Energies at Boundiali or community readiness at Elokato.

There is a strong case for expanding the role of local governments and cooperatives in the planning, monitoring, and even partial ownership of energy projects. Local ownership not only increases project buy-in but also strengthens maintenance and

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[74] Tenenbaum, B., Greacen, C., & Siyambalapitiya, T. (2014). From the Bottom Up: How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa. The World Bank. https://openknowledge.worldbank.org/handle/10986/16571 - Examines the role of tiered tariffs and mini-grid viability with attention to affordability and cost-recovery models.

long-term sustainability. Programs to train local technicians, provide financing for community energy committees, and facilitate dialogue between residents and national planners can bridge the gap between top-down planning and on-the-ground realities[75].

The training and upskilling of rural energy technicians should also be prioritized. A nationwide certification program for solar PV installers and micro-grid managers, potentially supported by TVET institutions and NGOs, could be a catalyst for employment creation and system reliability.

4.2.4 Fostering Public-Private Partnerships and Blended Finance

As demonstrated by the Boundiali Solar Power Station, blended finance is not just a theoretical model but a practical pathway for mobilizing capital at scale. However, such models are underutilized in decentralized projects due to smaller ticket sizes and higher perceived risk.

To foster private sector engagement, Côte d'Ivoire could establish a dedicated Renewable Energy Investment Facility, backed by the state and supported by donors. This facility would serve as a centralized vehicle to co-finance solar mini-grids and utility-scale plants, derisking investments via concessional loans, guarantees, and insurance mechanisms.

Moreover, frameworks that clarify Power Purchase Agreements (PPAs), establish transparent procurement practices, and support long-term financial sustainability are essential. Lessons from East Africa show that bankable PPAs, when standardized and legally enforced, can unlock investment flows even in lower-income contexts. Côte d'Ivoire should ensure that the legal environment for renewable energy is robust, predictable, and harmonized with regional goals[76] under ECOWAS and the West African Power Pool.

4.2.5 Integrating Electrification with Broader Rural Development

[75] SEforALL. (2021). Powering Jobs Census 2021: The Energy Access Workforce. Sustainable Energy for All. https://www.seforall.org/data-stories/powering-jobs-census-2021 - Discusses how empowering local communities with training and job opportunities can improve system sustainability.
[76] ECOWAS. (2020). ECOWAS Renewable Energy Policy Implementation Guidelines. Economic Community of West African States. https://ecowrex.org/ - ECOWAS guidelines on regional renewable energy targets and harmonization of legal frameworks.

Electrification cannot be viewed in isolation. As seen in the regression analysis and qualitative cases, access to electricity only translates into poverty reduction when accompanied by other enablers — such as healthcare, education, water access, and market integration.

The government should consider bundling electrification programs with complementary investments in rural development. For example, electrified zones could be prioritized for agribusiness hubs, ICT access points, and rural health clinics. This strategy would not only increase demand and system utilization but also generate inclusive economic returns[77].

Furthermore, data collection and impact monitoring should be institutionalized to track how energy access translates into development outcomes. Existing tools such as the Multi-Tier Framework (MTF) can help capture nuanced energy access metrics and guide adaptive policy implementation[78].

4.3 The Role of Financial Institutions and Donors

The acceleration of electrification in sub-Saharan Africa, and particularly in Côte d'Ivoire, cannot be decoupled from the evolving role of financial institutions and international development actors. As both of the analyzed case studies demonstrate, access to energy infrastructure in low-income and rural contexts depends not only on technical feasibility or community demand, but also — crucially — on access to finance[79]. Financial institutions shape the scale, design, and replicability of energy interventions, either by underwriting the initial capital costs or by shaping the financial conditions under which such projects become bankable.

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[77] Barnes, D. F., & Foley, G. (2004). Rural Electrification in the Developing World: A Summary of Lessons from Successful Programs. The World Bank. https://documents.worldbank.org/ - Identifies how coupling energy projects with health, education, and enterprise hubs increases development impact.
[78] Bhatia, M., & Angelou, N. (2015). Beyond Connections: Energy Access Redefined. Energy Sector Management Assistance Program (ESMAP), World Bank. https://openknowledge.worldbank.org/handle/10986/24368 - Introduces the Multi-Tier Framework (MTF) to capture more detailed metrics of energy access quality and development relevance.
[79] Access to finance is consistently cited as a critical bottleneck in rural electrification projects across Sub-Saharan Africa. See: World Bank. (2017). Rethinking Power Sector Reform in the Developing World. https://openknowledge.worldbank.org/handle/10986/28982

In the Elokato-Bingerville case, the financing model is indicative of small-scale, community-oriented solar interventions. The project assumes a simplified cooperative model or donor-subsidized capital injection, which reflects broader trends in rural electrification, where affordability constraints prohibit pure market-based approaches. In such settings, upfront costs often exceed what rural consumers can afford, creating what has been termed a "viability gap." Donor support, grants, and concessional capital are therefore critical in subsidizing capital expenditures (CAPEX) and reducing long-term tariffs to affordable levels[80].

Indeed, the analysis aims to encourage the potential engagement from microfinance institutions or public-private partnerships to solve this problem. This strategy of blended support is already present and progressively widespread in rural Africa, especially in places where institutions like the African Development Bank (AfDB) and the World Bank have already launched context-specific programs such as the Sustainable Energy Fund for Africa (SEFA) or the Scaling Mini-Grid initiative[81] in order to provide concessional funds for rural electrification projects.

Instead, the Boundiali Solar Power Station shows how international finance can help improve national-scale infrastructures. In this case, the €40 million investment was composed of both public and private capital, including €27 million in concessional loans from the German Development Bank (KfW), €9.7 million in grants from the European Union, and another contribution from the Ivorian Government. This financing scheme translates a strategy to share the risk of the investment[82]. Indeed, development finance institutions (DFIs) absorb an important portion of the risk, thus lowering the cost of capital and attracting co-financing from private entities. Furthermore, initiatives such as the long-term Power Purchase Agreement (PPA) with Compagnie Ivoirienne d'Électricité (CIE) further improved the confidence of private investors.

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[80] Grants and concessional financing play a vital role in bridging the viability gap in rural energy projects. See: Lighting Global, World Bank Group. (2018). Off-Grid Solar Market Trends Report 2018. https://www.lightingglobal.org/resource/market-trends-report-2018/

[81] These initiatives are aimed at accelerating mini-grid deployment in underserved regions. See: AfDB. (2022). Sustainable Energy Fund for Africa (SEFA). https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/sustainable-energy-fund-for-africa

[82] Risk-sharing through blended finance is essential to make large infrastructure projects bankable. See: OECD. (2018). Making Blended Finance Work for the Sustainable Development Goals. https://doi.org/10.1787/9789264288768-en

This different manner of financing – donor-driven and localized in Elokato, versus internationally syndicated and utility-scaled in Boundiali – also translates the difficulty in choosing best between centralization and decentralization when it comes to energy planning.

In both models, however, financial institutions play a role not simply as funders but as system designers. Through their financing conditions, they influence project governance, sustainability, procurement standards, and the extent to which local content is incorporated into implementation. Donors and DFIs, especially those operating under climate finance frameworks such as the Green Climate Fund (GCF), often tie disbursements to environmental and social safeguards, gender equity targets, and policy alignment — thus shaping the wider development impact of each intervention.

Something relevant to notice is that financial institutions are not only important to finance the projects. For example, in the Boundiali case, EU and KfW gave their support to also build capacities, assess the feasibility of the projects, and make Environmental and Social Impact Assessments (ESIAs), thus helping to institutionalize best practices in Côte d'Ivoire's energy sector. In small, rural projects like Elokato, there are often no formal Environmental and Social Impact Assessments (ESIAs) or detailed, reliable financial models that would make the project appealing to banks or institutional investors[83]. This lack of standard documentation or planning makes lenders cautious, because they can't properly assess the risks or predict returns.

The World Bank's Energy Sector Management Assistance Program (ESMAP) has documented that early-stage financing and pre-investment support often constitute the missing link in rural solar deployment[84].

Moreover, the degree to which financial actors can replicate and scale successful interventions depends heavily on national policy coherence. In this regard, Côte d'Ivoire has made significant progress by articulating targets under its National Renewable Energy Action Plan (PANER) and aligning donor-supported projects with the goals of PRONER

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[83] The absence of standardized ESIAs and financial documentation limits access to commercial capital for mini-grid developers. See: International Finance Corporation (IFC). (2021). Unlocking Private Investment in Mini-Grids. https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/infrastructure/resources/unlocking+private+investment+in+mini-grids

[84] ESMAP identifies early-stage capital and project preparation as key barriers to scaling rural solar. See: ESMAP. (2019). Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. https://www.esmap.org/node/71262

and the SDGs. The challenge, however, lies in harmonizing centralized utility-scale finance with decentralized off-grid initiatives — two tracks that often attract different donor mandates, risk profiles, and regulatory frameworks.

In summary, financial institutions are not merely sources of capital; they are central architects in shaping the direction and scale of energy access programs. Their role spans funding, de-risking, policy advising, and standard setting. For Côte d'Ivoire to reach universal access by 2030, a blended finance approach that combines donor support, private capital, and strategic public investment will remain indispensable. The two projects analyzed — Elokato and Boundiali — offer contrasting but complementary pathways to that goal. One illustrates how localized solutions require tailored financial instruments and institutional innovation; the other demonstrates the viability of grid-connected solar energy at a national level when backed by credible international partnerships.

4.4 Financing and Partnership Models

Expanding access to solar energy in Côte d'Ivoire, particularly in rural and underserved areas, depends not only on technological viability or political will, but critically on the structure and availability of finance. Both case studies analyzed — Elokato and Boundiali — illustrate the importance of tailored financial instruments and partnerships. While Boundiali benefited from large-scale concessional lending and institutional alignment, Elokato suffered from an unclear funding mechanism, revealing critical challenges in replicating decentralized solutions at scale. In line with the research question of this thesis – we were wondering at the beginning how can financial systems be designed to serve both the needs of investors and the realities of rural communities and what policy frameworks are necessary to ensure long-term impact - this last section aims at outlining three credible financing models and three partnership frameworks that could enhance bankability, de-risk investment, and enable inclusive electrification across the country.

Innovative Financing Mechanisms

- **Results-Based Financing (RBf) for Decentralized Systems**

One key barrier identified in Elokato was the absence of a clear financing structure. While the technical feasibility was strong, the lack of a bankable model undermines replicability. To address this, Results-Based Financing could be adopted. Under this approach, developers or energy service providers are reimbursed only upon delivery of measurable results, such as number of households electrified, or kilowatt-hours delivered.

This would reduce upfront capital constraints for small developers while ensuring public or donor funds are only disbursed upon verified outcomes[85]. Rwanda and Kenya have successfully implemented RBF in rural mini-grid programs with World Bank support, achieving cost-effective electrification with verifiable impact. In Côte d'Ivoire, such a mechanism could be administered through the Fonds d'Accès à l'Énergie Durable (FAED), a national energy access fund under development.

"The RBF model supports scalability and transparency, while minimizing financial waste by tying payments to tangible milestones" [85].

- **Local Currency Green Bonds**

A key vulnerability for both Elokato and Boundiali is foreign exchange risk. For Boundiali, the reliance on euro-denominated loans and imported components exposes the project to currency volatility. One solution is the issuance of local currency green bonds via the regional stock exchange (BRVM), with guarantees from international institutions (e.g. AfDB or MIGA).

These bonds could pool capital for renewable energy infrastructure while enabling Ivorian pension funds and institutional investors to enter the energy space. The success

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[85] Results-Based Financing (RBF) mechanisms have been shown to enhance accountability and efficiency. See: World Bank. (2015). Results-Based Financing in Energy Access. https://openknowledge.worldbank.org/handle/10986/22292

of Nigeria's Sovereign Green Bond in 2017 demonstrates that such instruments are feasible in West Africa when supported by regulatory stability and investor outreach.

"Green bonds enable long-term financing while reducing currency mismatch in renewable energy investments".[86]

- **Blended Finance and First Loss Guarantees**

To attract private finance into rural electrification, particularly in smaller projects like Elokato, de-risking instruments such as first-loss guarantees are essential. Through blended finance — combining grants, concessional loans, and commercial capital — donors or multilateral development banks (MDBs) can absorb initial losses, thereby improving project bankability.

For example, a guarantee facility operated by the West African Development Bank (BOAD) or GCF-backed platforms could absorb early-stage risk for projects under $1 million[87]. This approach was recently piloted in Burkina Faso's Yeleen project and could be adapted for mini grids in Côte d'Ivoire.

"First-loss capital acts as catalytic capital to crowd in private investors in early-stage energy markets".[88]

Strategic Partnership Models

- **Community-Private Sector Energy Cooperatives**

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[86] Green bonds in local currency reduce foreign exchange risk and increase participation by domestic investors. See: Climate Bonds Initiative. (2021). Green Bonds Market Summary – H1 2021. https://www.climatebonds.net/resources/reports/green-bonds-market-summary-h1-2021

[87] First-loss facilities are increasingly being used in West Africa to catalyze private investment. See: Convergence. (2020). The State of Blended Finance 2020. https://www.convergence.finance/resource/155fqX3rMWDUNgGOWO4BfF/view

[88] Convergence. (2020). The State of Blended Finance 2020. Convergence.
This report analyzes global blended finance trends and explains how first-loss capital provided by development institutions can unlock private capital in high-risk sectors like renewable energy. https://www.convergence.finance/resource/155fqX3rMWDUNgGOWO4BfF/view

One critical challenge in Elokato was ensuring long-term operational sustainability and payment recovery. A viable solution could be the development of local energy cooperatives, where ownership is shared between the community and the private operator. These models are widely used in Latin America and allow local users to have a stake in system maintenance, tariff setting, and grievance mechanisms.

Such models are especially effective when combined with smart meters and pre-paid platforms, enhancing revenue collection. In Côte d'Ivoire, where microfinance and community structures are already embedded in rural life, this model could be introduced through pilot programs supported by the Ministry of Energy.

"Cooperatives embed local ownership, improve payment behavior, and ensure long-term sustainability".[89]

- **Public-Private Partnerships with Output-Based Aid**

The Boundiali project demonstrated the power of public–private collaboration, but it remains an isolated case. To replicate such success at scale, Output-Based Aid models could be introduced within PPPs. Under this structure, a private developer finances and constructs a renewable project, while the government or donor agency commits to partial reimbursement based on service delivery — e.g., number of connections, hours of electricity provided.

This structure aligns incentives between public goals and private efficiency. The World Bank's Lighting Africa program has already piloted similar frameworks and could serve as a reference for CIEnergies and CI-Energies to implement regionally differentiated OBA programs.

[89] Glemarec, Y. (2017). Unlocking Private Energy Investment in Sub-Saharan Africa: A Guidebook for Public Investment Institutions. UNDP. This guidebook explores cooperative and blended models for off-grid electrification, showing how local ownership through cooperatives enhances financial sustainability and community engagement.
https://www.undp.org/publications/unlocking-private-energy-investment-sub-saharan-africa

"OBA structures ensure results while leveraging private sector expertise and investment capacity".[90]

- **Energy Access Investment Platform**

In order to achieve scale, Côte d'Ivoire may benefit from a dedicated Energy Access Investment Platform — a structured vehicle that aggregates small-scale solar projects into a single investment portfolio. This would address the challenge of transaction costs and scale limitations, particularly for projects like Elokato.

Such a platform could be managed by a national development bank or in collaboration with ECOWAS institutions. By pooling technical assistance, due diligence, and capital access, it would allow developers to benefit from economies of scale in procurement and financing. The Off-Grid Energy Access Fund (OGEF) in East Africa provides a successful model to replicate.

"Aggregation vehicles reduce risk, unlock capital, and streamline energy access pipeline development".[91]

Overall, the policy implications, budgeting, and institutional considerations discussed in this chapter reflect the complex nature of Côte d'Ivoire's solar electrification. Be it decentralized micro-grid initiatives or utility-based grid-connected plants, the success of future interventions will depend on collaborative planning, stakeholder management, and innovative financing. As the country continues to develop towards electrification and sustainability, the practical lessons from the Boundiali and Elokato-Bingerville projects can serve as handy models. These experiences blended with the policy and financial recommendations outlined above provide a foundation for building

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[90] World Bank. (2016). Output-Based Aid: Improving Access to Infrastructure for the Poor. World Bank Publications.
This report outlines how Output-Based Aid (OBA) mechanisms align incentives in infrastructure projects, particularly in energy, water, and health sectors, by tying disbursement to verified service delivery.
https://documents.worldbank.org/en/publication/documents-reports/documentdetail/928891468196135040/output-based-aid-improving-access-to-infrastructure-for-the-poor

[91] African Development Bank. (2020). Off-Grid Energy Access Fund (OGEF): Project Overview. Sustainable Energy Fund for Africa (SEFA). The OGEF platform aggregates smaller solar energy projects across Sub-Saharan Africa, reducing transaction costs and improving financing efficiency for off-grid electrification.
https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/sefa/off-grid-energy-access-fund

replicable, inclusive, and climate-resilient energy systems. The following concluding section addresses these results in the context of national development, climate action, and equitable energy access.

CONCLUSION

Availability of cheap, clean, and green power remains the master driver of Côte d'Ivoire's and Sub-Saharan Africa's socio-economic development, respectively. This thesis started by pointing out the historical rural electrification deficit and suggested distributed solar energy systems—solar micro-grids specifically—as an operational answer to supplying clean power where it is not feasible to expand the national grid. In the process of doing this, though, it also acknowledged that if these solutions are to be successful, they need to be economically viable, responsive at the local level, and adequately funded.

The main question that led to this research was how Côte d'Ivoire can increase solar electrification—particularly to rural areas—through technologically and economically sustainable models. In addition, the thesis explored the contribution of financial institutions, public-private partnerships, and banks in removing structural barriers to solar energy investment, and whether new financing modalities have the ability to address the gap between investor expectations and rural realities.

For assistance with these questions, two seemingly opposing yet complementary case studies were investigated: the Elokato-Bingerville micro-grid and the Boundiali Solar Power Station. Elokato was a bottom-up decentralized solar power process structured on a community model. It displayed the way tailored micro-grid systems are able to adapt to specific local demand and promote rural inclusive development[92]. However, it also revealed original limiting factors—such as restricted access to finance, lack of formal ESIA procedures, and challenges to long-term maintenance—that constrain bankability and scaling-up potential.

Alternatively, the Boundiali project illustrated the merits of utility-linked, scale-building infrastructure with potential to significantly increase national power generation capacity and access to concessional financing. Its funding model—rooted in a collaboration between CI-Energies, the German Development Bank (KfW), and the

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[92] Cross, J., & Murray, D. (2018). Off-grid solar electricity adoption in developing countries: What do we know? Wiley Interdisciplinary Reviews: Energy and Environment, 7(1), e268.
This paper investigates how micro-grid and off-grid systems are adapted to rural needs, and underlines their capacity to support inclusive development through community ownership and tailored design.
https://doi.org/10.1002/wene.268

European Union—proved how collaboration at an international level and blended finance can de-risk projects and raise capital at scale[93]. Still, Boundiali's centralized design also meant reduced responsiveness to local needs, limited long-term employment opportunities, and the risk of technological dependency on external actors.

The case studies together validate a valuable adage: there is no one model of electrification. Instead, Côte d'Ivoire must have a mixed energy strategy that includes both centralized utility-scale power stations and decentralized micro-grid systems. Where high plants can grid-stabilize and complement national goals, smaller ones must be deployed to supply remote regions and extend development to the many. For the twin strategy to work, funding channels need to be diversified and aligned with each model's risk profile and size.

Among the core contributions of the thesis was to suggest new partnership and financing mechanisms that would support this hybrid approach. Through examination, several approaches—RBF, Local Currency Guarantees, and Community-Based Co-Investment—were found to be workable means of bridging rural finance gaps[94]. With institutional innovations like decentralized energy planning and performance-based subsidies, the aforementioned mechanisms can likely increase project bankability substantially while being context-responsive.

Wider still, this research put under the spotlight the need to re-imagine what is a bankable project in rural electrification. Unconventional commercial opportunities are projects supplying electricity to remote, poor communities, but with strong socio-economic returns. Laying this value out through putting finance, policy backing, and capacity-building support together is how to tap into long-term development potential and make clean power not only available, but accessible to everyone.

Briefly, solar power in Côte d'Ivoire is not just a technical fix—it is a transformational opportunity to wed energy access with inclusive growth, financial

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[93] OECD. (2018). Blended Finance in the Least Developed Countries 2018: Supporting a Century of Progress. OECD Publishing. This report provides key insights into how blended finance can attract private capital for public goals, especially in energy and infrastructure sectors in low-income contexts. https://www.oecd.org/publications/blended-finance-in-the-least-developed-countries-2018-9789264307648-en.htm

[94] SEforALL. (2021). Energizing Finance: Understanding the Landscape 2021. Sustainable Energy for All and Climate Policy Initiative. This report explores innovative financing mechanisms for energy access in developing countries, highlighting results-based financing, local-currency bonds, and co-investment schemes.
https://www.seforall.org/data-and-evidence/energizing-finance-series/understanding-the-landscape

innovation, and climate leadership. But translating this potential into reality will require further public-private partnership, locally led investment planning, and continued commitment to equity in energy planning. Given the right support of policies, finance, and public awareness, Côte d'Ivoire can become a beacon of example in how a sustainable model for an energy transition can be achieved in West Africa and elsewhere[95].

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[95] IRENA. (2022). Renewable Energy Market Analysis: Africa and its Regions. International Renewable Energy Agency.
This report provides an in-depth overview of Africa's renewable energy transition, highlighting Côte d'Ivoire as an emerging leader in sustainable electrification through solar and hydropower.
https://www.irena.org/publications/2022/Jan/Renewable-Energy-Market-Analysis-Africa

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