分类号：　　　　　　　　　　学校代码：10363
密　级：　　　　　　　　　　学　　号：

安徽工程大学
Anhui Polytechnic University

# 硕士学位论文

题目 **CREATING CO-BENEFITS FROM CHINA - AFRICA INVESTMENT IN RENEWABLE ENERGY**


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研究方向 产业经济学

论文提交日期： 2025 年 5 月 6 日

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# ACKNOWLEGDEMENT

I would like to express my deepest appreciation to everyone who as given there full support for the completing of the research paper.

I extend my deepest gratitute to my supervisor Zhang Fang for providing me with the valuable advice and unrelenting support throughout my research journey. Her deep commitment to academic excellence and meticulous attention to detail have significantly shaped this dissertation.

My appreciation also goes to the faculty and staff in the School of Economics and Management, whose resources and assistance have been invaluable. I would also like to acknowledge my peers for their camaraderie and the stimulating discussions that inspired me throughout my academic journey. Their collective wisdom and encouragement have been a cornerstone of my research experience.

To my friends and family for the constant encouragement, patience and understanding have been the pillars of the success to the dissertation.

Thanks to everyone for shaping this dissertation and enhancing my learning experience.

# COMPETING INTEREST

The writer declare there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this dissertation.

# AUTHOR’S CONTRIBUTION

The writer confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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# ABSTRACT

***In sub-Saharan Africa, investments in renewable energy are growing quickly. Examining the degree and circumstances in which these expenditures are generating economic co-benefits in the form of spillovers and linkage development impacts is the main goal of this article. The quick rise in Chinese participation in major renewable energy infrastructure projects, as well as its anticipated future expansion, is one unique aspect of Africa's renewable energy market. Information from other sub-Saharan African infrastructure, utility, and resource extraction sectors points to China's pursuit of a particular Chinese investment model that includes financing, turnkey project development, and the importation of labor and equipment from China. This model is characterized by enclave characteristics.***

***Therefore, our goal in this article is to ascertain the degree to which Chinese investors' development of renewable energy projects results in economic co-benefits. In order to accomplish this, we use primary data to conduct a thorough analysis of three Chinese renewable energy investment projects in solar PV, wind, and hydro. Overall, we discover proof of "bounded benefits." On the one hand, we may see some recently established employment, connections made with local players in production systems, and training exercises that involve local employees.***

***However, the scope of these advantages is extremely constrained. Overall, the findings indicate that when evaluating the co-benefits of renewable energy projects in light of limited pre-existing capabilities, policymakers should exercise caution and avoid having unrealistic expectations. However, the local economic co-benefits can be increased by the implementation of well-thought-out policies and the adoption of proactive tactics.***


***KEYWORDS: Economic co-benefits, Renewable energy, Investment-centred global value chains, Infrastructure projects, China, Africa***

# CHAPTER 1
# INTRODUCTION AND LITERATURE REVIEW TO THE RESEARCH TOPIC.

The power system in sub-Saharan Africa will need to be significantly expanded in order to meet the growing demand for electricity. It is anticipated that over the next 20 years, electricity generating capacity will double, with renewable energy sources making up three quarters of the new generation, with the majority of that coming from solar, hydro, and wind (IEA, 2020). Since most African countries continue to face energy shortages, the main advantage of this expansion is the ability to generate electricity, and since renewable energy is expected to dominate recent energy projections, lowering carbon emissions is also a major benefit. Although these advantages are important, new research on what motivates investments in the green transformation has revealed that supporters of green policies and practices frequently depend on the expectation of co-benefits (Dubash, 2013; Schmitz, 2017).

Therefore, the aim of this paper is to investigate the extent and conditions under which these large investments in renewable energy have economic co-benefits. In sub-Saharan Africa, the benefits in addition to generating electricity and preventing climate change include "job creation, improvement of local skills, and creation of income-generating activities. The renewable energy sector can become an integral part of local economies, integrated both through upstream supply chain, such as production of equipment components, and downstream energy related services, such as maintenance" (IRENA, 2013, p. 15; see also Sperling, Granoff, and Vyas, 2012).

We concentrate on investments made by companies in the People's Republic of China (henceforth referred to as "China") because it is the nation that has the largest investment portfolio in the power sector of sub-Saharan Africa. According to the International Energy Agency (IEA, 2016, p. 7), 30% of new capacity additions in sub-Saharan Africa are projects in which a Chinese company is the sole main contractor; 56% of these projects are in renewable energy, with hydropower accounting for the vast majority of these projects, but wind and solar energy are becoming more and more common.

According to information gathered from other sub-Saharan African infrastructure, utility, and resource extraction sectors, China is pursuing a particular Chinese investment model that includes enclave features like financing, turnkey project development, and the importation of labor and equipment from China (Kaplinsky and Morris, 2009; Sanfilippo, 2010; Wegenast, Krauser, Strüver, and Giesen, 2019). Hence our focus in this paper is to what extent economic co-benefits arise in sub-Saharan Africa when renewable energy projects are developed by Chinese investors: *What is the potential for benefiting from Chinese renewable-energy investments in terms of employment, localisation of the value chain and technological learning?* In order to seek insights into this question, we focus on investments in hydro, wind and solar energy for electricity generation.

With the increasing attention paid to Chinese renewable energy investments in sub-Saharan Africa and the economic opportunities associated with them, there are few studies, let alone systematic analyses, in the existing literature (Shen and Power, 2016). Previous studies have calculated the volume of investments at an aggregate level (Chirambo, 2018; Shen, 2020), focused on the underlying drivers behind the increasing Chinese investments in renewable energy in Africa (Shen and Power, 2016) and the political economy of Chinese investments (Baker and Sovacool, 2017; Power et al., 2016).

Moreover, previous research in this field has focused mainly on large Chinese hydro-power projects (Brautigam and Hwang, 2019; Hensengerth, 2018), but with notable exceptions there are only limited data and information on specific Chinese developed solar photovoltaic (PV) and wind-power projects (Chen, 2018). In this paper, we introduce some conceptual and empirical reference points for future research, which is important in a field that lacks in-depth analysis. We do this by developing a conceptual framework for the systematic comparison of project-level cases across various renewable energy technologies, without offering statistical benchmarks.

For proper enlightenment, the core of our analysis is an examination of three specific Chinese projects in hydro, wind and solar energy. By providing in-depth analysis of co-benefits in terms job creation, value-chain localisation and capability building, we hope to stimulate an informed discussion of the conditions and policy measures which may maximise the local benefits of these investments. This is prefaced by a broader examination of renewable-energy investments with Chinese characteristics undertaken by dissecting China's involvement in the chosen renewable-energy sectors in sub-Saharan Africa by providing macro-data and by bringing out key aspects of the organisational models involved in such investment projects, including the key actors and their relationships.

## 1.1 DEFINITION OF TERMS

**1.1.1 Renewable energy:** Renewable energy sources are generated directly from nature for example, from the sun, rain, wind, tides, and it is possible to generate it over and over whenever it is needed. Renewable energy sources are abundant and are definitely the cleanest energy sources in Earth. Many types of Renewable energy sources are solar energy, biomass energy, wind energy, tidal energy, hydro energy, and geothermal energy. For instance, it is possible to use the energy from the sun and that is converted into electricity. Geothermal, wind, tides, and biomass energy from plants can also be used in different forms like Wind is harnessed from Earth's natural weather patterns. Hydro power comes from flowing rivers and from reservoirs. Solar energy comes from the Sun's light and radiation. Geothermal energy comes from the heat produced by the Earth underneath the ground.

The advantages of Renewable energy is that wind, sun, ocean, and geothermal energy is in abundance and completely free of charge. The renewable energy sources have very low or zero carbon emissions, so they are environmental friendly. The another advantage is, it is not necessary to rely on any country to supply renewable energy sources, unlike its non-renewable counterparts.

**1.1.2. Non renewable energy:** Non-renewable energy sources are not environmental friendly and can have serious affect on our health. Most energy that is used in the world today is generated from non-renewable energy sources. These energy sources can be re-generated over a short period of time. Natural gas and oil are derived from ancient plant or animal remains or fossils. These remains are what we have been left with after millions of years of fluctuation in pressure and temperature. Non-renewable energy sources include oil, coal, natural gas, and nuclear energy. The advantage of non-renewable energy sources are it is ready, cheap, and easy to use. The non-renewable energy convert one non-renewable energy type to another. The major disadvantage of non-renewable energy sources is that they are finite and will expire sometime in the future. This will make the prices of these non-renewable energy sources increase dramatically. They also cause severe environmental changes and are in a large way responsible for climate change and global warming. Non-renewable energy sources can have a serious impact on human health, as they are certainly not environmental friendly.

**1.1.2 Economic co-benefits:** The Intergovernmental Panel on Climate Change (IPCC) defines co-benefits as 'the positive benefits related to the reduction of greenhouse gases'. It includes 'economic co-benefits', such as energy security, increased employment and technological innovation (IPCC, 2007).

## 1.2. GLOBAL DEVELOPMENTS IN GREEN INVESTMENTS AND RENEWABLE ENERGY TECHNOLOGY.

Several studies have predicted that renewable energy technologies will experience rapid growth in the upcoming years, based on data currently available on patterns in energy technology investment and capacity development. Over the last ten years, there have been notable advancements in technology and cost reductions that have coincided with the expansion of markets for renewable energy. The new technologies, however, must contend with those derived from fossil fuels and rely on the general shift in demand. A common way to investigate the diffusion of energy technologies is through the use of model-based scenarios, offering a systematic exploration of possible energy futures. In this respect, the World Energy Outlook (WEO) develops four scenarios for the world energy system: **the "Current Policies Scenario", the "New Policies Scenario" (NPS), the "450 parts per million of carbon-dioxide equivalent Scenario", and the "Efficient World Scenario". (IEA, 2012)**. The NPS details the impact of existing policy commitments and the implementation of those recently announced on key energy demand, supply, trade, investment and emissions trends in the period up to 2035. In this scenario, fossil fuel subsidies will have been phased out by 2020 in all net energy importing countries and more gradually in exporting countries that have announced plans to do so.

The WEO 2012 uses the World Energy Model that replicates the dynamics of energy markets based on historical data on economic and energy variables to generate projections. Global primary energy demand is expected to rise by 35% between 2010 and 2035, according to the NPS. The proportion of fossil fuels will drop from 79 percent in 2020 to 75 percent in 2035, although gas, coal, and oil will still be the main energy sources. The share of renewable energy sources in the world's primary energy consumption is expected to increase from 15% in 2020 to 18% by the end of 2035.

## 1.3. RENEWABLE ENERGY INVESTMENT.

The UNEP (2013) reports that, excluding roughly USD 33 billion in large-scale hydroelectric projects, global investments in renewable energy in 2012 totaled USD 244 billion for renewable energy power and fuels. South Africa was not the only African country to embrace renewables; Morocco also saw a surge in outlays, from USD 297 million to USD 1.8 billion, while Kenya saw outlays of USD 1.1 billion in 2012, up from nearly zero in 2011. The total amount of investment in developing economies increased 19 percent to USD 112 billion in 2012, while investment in developed countries fell 29 percent to USD 132 billion.

Morocco committed to two large projects in 2012: the MASEN Ouarzazate CSP power plant phase one (at 160 MW and USD 1.2 billion) and the Nareva led Tarfaya Wind Farm (at 300 MW and USD 563 million). In Kenya an investment of USD 900 million was committed for the 400 MW Menengai geothermal project phase one and USD 180 million for the 36 MW Ormat Olkaria geothermal project expansion phase one.

The Middle East and Africa experienced a steep threefold increase in investments in renewable energy between 2011 and 2012. It can generally be said that a shift in RET investments has taken place from the "North" to the "South" over the last years.

A 12 percent decline in global investments in RETs in 2012 was a break from the trend, primarily due to investor concerns about policies to support renewable energy in the US and Europe, the two markets with the longest histories. Other factors that contributed to the overall negative trend included pressure on utility balance sheets in Europe, retroactive cuts in support for renewable energy in some European countries (such as Spain), and the poor performance of clean energy share prices.

# CHAPTER 2
# LOCAL DEVELOPMENT AND GLOBAL INVESTMENTS IN RENEWABLE ENERGY

The idea that energy transformations may go hand in hand with opportunities for economic development is gaining increasing traction, not least in advanced economies (Capasso, Hansen, Heiberg, Klitkou, and Steen, 2019), but also in emerging economies such as China and India (Altenburg, Sagar, Schmitz, and Xue, 2016; Schmitz, 2017). The same claim has been made for countries in sub-Saharan Africa (AfDB, 2016; Sperling et al., 2012): 'In Africa, green growth will mean pursuing economic growth through policies, programs and projects that invest in sustainable infrastructure...' (Sperling et al., 2012, p. 5).

However, there is very little evidence of the real economic opportunities associated with green investments and policies in low- and lower middle-income countries (Pegels and Altenburg, 2020). This paper attempts to fill this gap by collecting information on the developmental impacts and economic opportunities from case studies of leading green energy projects in sub-Saharan Africa. In this section, we present a customized conceptual framework for project-level analysis of the economic co-benefits linked to Chinese investments in renewable energy in Africa. The framework offers a heuristic analytical tool for exploratory empirical analysis.

## 2.1. CO-ADVANTAGES OF SUB-SAHARAN AFRICAN GREEN ENERGY PROJECTS FROM CHINA.

In this study, we concentrate on the idea of "economic co-benefits" that result from Chinese renewable energy investment projects in sub-Saharan Africa's electrical grid. These are the additional benefits that can potentially accompany the green-energy transition (Wesseh and Lin, 2016). As such, the co-benefits may be distinguished from the primary benefits that motivate the investment, here the creation of a renewable-energy infrastructure and its subsequent use in supplying electricity (Dubash, 2013; Schmitz, 2017). Co-benefits are local welfare gains, defined here as the positive economic effects arising in and from renewable energy investments.

Our foundational framework for exploration research is shown in Fig. 1. It seeks to capture the key components of the transnational investment–production complexes that surround Chinese green energy infrastructure investment projects and the economic benefits that accompany them. The framework reflects the knowledge that local institutional and economic conditions, which can differ greatly between nations and cases, as well as broader China-African relationships involving economic and political power, influence projects.

The scope and character of these economic co-benefits constitute a significant portion of our empirical study, but we also aim to investigate issues regarding their causes. The following is a discussion of the main components of this framework.

## 2.2. INVESTMENTS, VALUE CHAINS AND LOCAL INSTITUTIONS AND GREEN ENERGY PROJECT.

Based on the existing literature, elaborated below, we expect that local economic co-benefits will depend on three main interdependent factors which are summarised in Table 1. We will be discussing these accordingly.

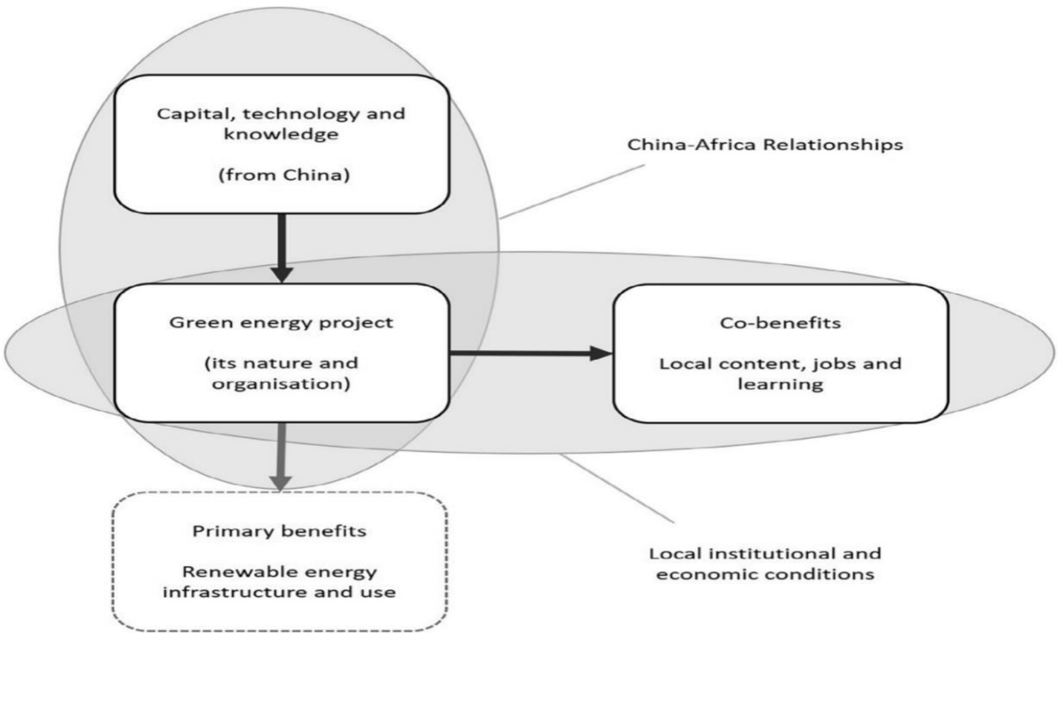


***Fig. 1. Framework for exploratory research Note: the figure maps the key analytical building blocks examined in this study. Solid black arrows depict the main relationships in primary data collection and analysis.***

**Table 1**

**Factors for exploratory research.**

| Factor/variable/unit of analysis | Characteristics | Key references |
|---|---|---|
| Nature and flows of capital and technology | - Technologies and their components<br>- Lead agents involved<br>- The nature of finance | (*Brautigam and Hwang, 2019; Kaplinsky and Morris, 2009; Lema, Hanlin, Hansen, and Nzila, 2018*). |
| Local institutional and economic conditions | - Host-economy deployment model<br>- Industrial policy environment<br>- Domestic supply base | *(Baker and Sovacool, 2017; McCrudden, 2004; Power et al., 2016).* |
| The nature and organisation of the investment project | - Contractual arrangements<br>- Planned capacity-building<br>- Project organisation | *(Hanlin, Okemwa, and Gregersen, 2019; Hansen et al., 2018).* |

## 2.3. THE NATURE OF INBOUND FLOWS OF CAPITAL AND TECHNOLOGY FROM CHINA.

The literature on Chinese foreign direct investments in sub-Saharan Africa, including investments in general infrastructure and natural resource extraction, has described a typical ‘Chinese model’ with tight bundling of investment finance and supply chains (Cabré, Gallagher, and Li, 2018; Calderón and Servén, 2010; Kragelund, 2009; Wegenast et al., 2019). Kaplinsky and Morris (2009) draw on perspectives drawn from the study of global value chains to describe how Chinese FDI in Africa bundles together aid, trade and FDI, driving how supply chains are managed by means of integrated consortium. In this paper, we focus on what (Lema, Hanlin, Hansen, and Nzila, 2018) refer to as ’investment-centred value chains’, which denote value chains driven by investment finance and centred on the development of large-scale capital-intensive projects. The main variables of the flows involved in these international investment chains are listed in Table 1, ranging from the type of capital transferred to the particular technology employed to the roles of finance and lead agents (the companies that control these chain interactions).

## 2.4 LOCAL INSTITUTIONAL AND ECONOMIC CONDITIONS

Another important determinant is the local context of project execution in terms of endowments of human and organisational capabilities, as well as the institutional and political environment. Outcomes depend crucially on existing supply chains and the capabilities of both local firms and project owners (Lema, Iizuka, and Walz, 2015). A highly asymmetrical distribution of capabilities between local and foreign (here Chinese) actors may limit the scope of co-benefit creation, as well as vice versa. Local bargaining power may be limited, but deliberately devised policies and strategies may influence the opportunity to reap benefits through models of project organisation and execution which deliberately seek to enhance their creation (Baker and Sovacool, 2017; Power et al., 2016). Institutional conditions and regulatory frameworks can play a key role in mediating these conditions, for example, by stimulating local production through local content requirements, public procurement regulations and industrial policies (McCrudden, 2004; Lema et al., 2018).

Specifically in the case of renewable-energy projects, a number of deployment models and related policies may be used to support their diffusion, ranging from market-based systems, such as auction schemes, to directly negotiated contracts on an individual basis, such as government-to-government agreements (Leigland and Eberhard, 2018; World Bank, 2016). Since competitive bidding systems can lower prices and guarantee transparency, they are generally being used more often around the world. However, as Shen (2020) has noted, Chinese investors prefer directly negotiated contracts over open bidding systems, like auction schemes, when it comes to entering the renewable energy sector in Africa.

**Table 2**

**Key co-benefits and indicators.**

| Type of Co-benefit | Characteristics | Key References |
|---|---|---|

| | | |
|---|---|---|
| Job creation | - Types of jobs in contracts<br>- Local jobs in project construction<br>- Local jobs in project operation<br>- Local jobs in project maintenance<br>- Local jobs in other project services | (Pahle et al., 2016; Suberu et al., 2013) |
| Local content | - Involving local firms and local supply chains<br>- Involving local universities and other knowledge institutions<br>- Involving local communities<br>- Access to infrastructure | (Hanlin and Hanlin, 2012; Hansen et al., 2020; Wells and Hawkins, 2010) |
| Technological learning | - Transfer of embodied or disembodied knowledge<br>- Inbound flows of equipment, designs/blueprints and management frameworks<br>- Interaction between supplier of the above and the local user<br>- Training of local staff<br>- Local staff secondment and training | (Bell, 2012; Ockwell and Mallett, 2013) |

## 2.5 THE INVESTMENT PROJECT'S STRUCTURE AND NATURE.

The potential for the creation of co-benefits depends on how a project is ‘organised’. The type of project organisation may range from full-package provision in which the investor and technology supplier cater for the full range of activities to highly open models in which a large number of activities are undertaken by local firms and user organisations (Lema et al., 2018). This depends in turn on the underlying contractual arrangements. In recent years, projects have tended to be organised in contractor-driven models, in which projects are driven and coordinated by a dedicated infrastructure service contractor and which reflect the trend towards private sector involvement in the growth of infrastructure industries such as independent power producers (IPPs) or non-utility generators (Bell, 2007; World Bank, 2016).

An empirical challenge in the contractor-driven model is to distinguish between different variations of project "anatomy." For example, it is helpful to distinguish between anatomies involved in infrastructure delivery (the plant) and service delivery (the use of the plant for electricity provision) for investment projects. A third element is the extent of planned capacity-building. Engineering, procurement, and construction (EPC) contracts are awarded to a single firm, which then subcontracts numerous tasks in the contract to product and service suppliers while supervising overall project management itself. A common contractual requirement is for the EPC contractor to develop the awarding entity's capacity so that it can run the asset and deliver the service after the contract expires. Such intentional efforts to increase capacity may, in theory, even include the provision of the infrastructure itself.

The findings, taken together, show a variety of technological, economic, and political factors in particular China-Africa relationships. Global flows and local conditions influence the nature and organization of the investment project, which may leave varying degrees of room for the realization of economic co-benefits. As a framework for exploratory analysis, we intentionally aim to reduce complexity while also being aware that the expansion of green energy is a highly contested and political process, as exemplified by the vertical and horizontal ellipses in Fig. 1.

## 2.6. ECONOMIC CO-BENEFITS

We look at three forms of co-benefits: employment, local content, and technological learning (Table 2). Since the core of our empirical research is concerned with benefits, it is vital to characterize them further.

- **Job creation:** Project investment may include various types of local jobs. Existing research has shown that the employment-creation potential and involvement of local labour differ with the type of renewable energy, the size of the project and the nature of the value chain (Hansen, Gregersen, Lema, Samoita, and Wandera, 2018). Local employment can be created at various stages throughout the chain, such as project construction, operation, maintenance, or other project services. Jobs in these functions may involve varied levels of skill and knowledge intensity.

- **Local content**: Foreign investment projects may be organised in very different ways depending on the type of technology involved, the availability of local supply chains for the creation of backward linkages, the investment strategy and the policies that regulate investments (Tsani, 2020; Wells and Hawkins, 2010). Local content refers to those services, materials and capital goods used to deliver the project that are local rather than imported, divided into direct content (in the project) and indirect content (in local supply chains).
- **Technological learning:** The extent to which local firms and related actors can use renewable energy investments to develop their own technological and organisational capabilities is significant because it increases the likelihood that these firms' actors will increase their competitiveness and ability to engage in future green investments and related activities over time. The literature on low-carbon technology transfers and technological learning in latecomer countries has emphasised how investments from outside differ in their learning potential (Bell, 2012; Hansen and Lema, 2019; Ockwell and Byrne, 2015). This is determined by the form of the knowledge flows, such as whether knowledge is embodied in machinery and equipment or whether it involves the transmission of people-embodied knowledge, such as site visits by the technology supplier or training visits by the technology recipient. It is crucial to emphasize that the types and quantities of economic co-benefits are difficult to quantify precisely. Furthermore, once an empirical investigation is completed, it is difficult to determine if the reported co-benefits are few/shallow or many/deep. This is because such an assessment can only be performed in connection to previous studies of a similar sort (which are few and far between) as well as a theoretical maximum of co-benefits that could potentially develop. To address this issue, we provide Appendix A2 which describes our composite indicators and helps to situate and interpret our findings.

## 2.7 RESEARCH DESIGN AND CASE SELECTION

The conceptual framework provided above (fig 1) was used to analyze the potential co-benefits and their determinants for the purposes of this study. We chose a case study technique for this work because it comprises exploratory research on a recent occurrence that has not before been thoroughly studied (Yin, 2013).

Wider phenomena are selected as representatives in this instance, and the wider phenomenon in question is the Chinese investment in the renewable energy sector in Africa. As a result, we only concentrate on China's role in Africa's renewable energy market (the research object), and we accomplish this by concentrating on investment projects (the unit of analysis), which is the standard organizational structure in the green energy industry. Therefore, the inclusion of Chinese project management and financing should be a commonality among renewable energy projects for the purposes of this study.

Having isolated these factors, the intention was to explore co-benefit creation under markedly different circumstances with respect to the technologies used and the local contextual conditions. Hence, the research uses a variation strategy to select cases. In using a variation sampling method, the researcher selects a small number of cases that includes diversity relevant to the research question and conceptual framework, while recognising the possibly of identifying common patterns across cases (Given, 2008).

We started this process by selecting projects that used three distinct renewable energy technologies: ***the Adama project in Ethiopia (wind energy), the Bui dam project in Ghana (hydro energy) and the Garissa project in Kenya (solar PV).*** (***With respect to technology selection, it is worth noting that hydro-power is an example of 'low-carbon' rather than 'sustainable' energy. Challenges in mitigating the environmental and social impacts of hydro-power dams are significant, as they have been found to harm fisheries and related livelihoods; the construction of hydro-power dams has replaced more than eighty million people in the past century (Kirchherr and Charles, 2016). Despite these vast negative impacts, a hydro-power surge is still under way, with more than 3,700 dams either planned or under construction (Zarfl et al., 2015).***

Therefore, These projects represent multiple case studies of China's involvement in the renewable energy sector in Africa, which have in common their Chinese-dominance while exhibiting variation across the explanatory factors in the framework (Seawright and Gerring, 2008). By applying a common conceptual framework to analyse these case studies we sought to enhance the internal validity of the findings (Gustafsson, 2017).

Therefore, the foundation of our research is based on original data that was acquired at the project level. Micro-level analysis examining incoming flows, local conditions, organizational arrangement characteristics, and the three primary co-benefit kinds were conducted using this data. Site visits to each project and 38 in-depth interviews with project organizers and key informants who possess pertinent project knowledge serve as the primary sources of information for these case studies. Additional details regarding data collecting in each example are included in the comments in Chapter 4. Given the lack of existing studies, the paper provides a first exploratory attempt to analyse the co-benefits and their determinants in Chinese projects. The findings presented in this paper thus provides a starting point for subsequent research, for example research aimed at comparing the performance of Chinese projects with projects involving non-Chinese investors and project developers. By providing concrete information on co-benefits, we contribute to the creation of 'benchmarks' regarding the types and levels of co-benefits that can function as reference points in the future (see also Appendix A2 for further discussion). Similarly, regarding the conditions for co-benefit creation, the findings presented in this paper are not generalizable in a statistical sense, but the insights generated from the analysis do allow us to derive case-specific findings that would be useful in generating hypotheses of theoretical relevance for further research (Eisenhardt and Graebner, 2007; Flyvbjerg, 2006).

# CHAPTER 3
# CHINA'S INVOLVEMENT IN SUB-SAHARAN AFRICA'S DEVELOPMENT OF RENEWABLE ENERGY.

An overview of China's role in the deployment of renewable energy in sub-Saharan Africa with respect to the three technologies covered in this article is given in this section. By discussing the patterns of capital and technology flows from China, we can look at the macro-evidence for the existence of a "Chinese model" of green-energy investments, which serves as a backdrop for the project-level analyses in the following sections.

## 3.1. CHINA'S TOTAL INFLUENCE ON THE ENERGY SECTOR IN SUB-SAHARAN AFRICA.

As it as been quoted, China is the largest investor in sub-Saharan Africa’s power sector. Chinese finance for the energy sector in Africa, including North Africa, amounted to a total of more than USD 30 billion over the sixteen-year period from 2000 to 2016, but this includes all energy sources, both black and green (Shen, 2020). However, according to the IEA (2016), in an analysis of Chinese greenfield energy investment projects which had been completed, were under construction or were planned for completion over the 2010–2020 period, 56% of Chinese energy generation projects were found to use sources of renewable energy. The total investments involved amounted to USD 13 billion across 37 countries.

**Table 3**

Total installed capacities of hydro, wind and solar power in Africa, 2009–2018 (MW).

| Technology | 2009 | 2018 | Countries with the largest share of total capacity |
|---|---|---|---|
| Hydro-power | 26 GW | 35 GW | Angola, Ethiopia, South Africa, Zambia |

| | | | |
|---|---|---|---|
| Wind power | 739 MW | 5.5 GW | Egypt, Ethiopia, Morocco, South Africa, Tunisia, |
| Solar Power | 108 MW | 6.1 GW | South Africa, Morocco, Egypt, Algeria, Kenya |

**Source**: *IRENA (2013, 2019).*

**Table 4**

Key Chinese financial institutions, EPC contractors and technology suppliers involved in the green-energy sector in sub-Saharan Africa.

| | Finance | EPC Contractors | Technology Suppliers |
|---|---|---|---|
| Hydro | ● China Export-Import Bank (China Exim Bank)<br>● Chinese Development Bank (CDB)<br>● Sinosure<br>● Industrial and Commercial Bank of China (ICBC)<br>● Bank of China (BoC) | ● Sino Hydro<br>● Power-China Resources<br>● Three Gorges Corporation | ● Dongfang Electric Corporation<br>● Harbin Electric Corporation<br>● Shanghai Electric Power |
| Wind | As above | ● CGC Overseas Construction Group<br>● Hydro China<br>● Longyuan Power Group | ● Gold-wind<br>● Sany<br>● Sinovel |
| solar | As above | ● China Jiangxi Corporation<br>● Power way<br>● Beijing Xiaocheng | ● JinkoSolar<br>● Yingli<br>● JA Solar |

***Source: Chirambo (2018), Shen and Power (2016) and Tan-Mullins, Urban, and Mang (2017)***

Chinese investors made up 60% of sub-Saharan hydropower project investments, according to Table 3, which displays installed capacity in sub-Saharan Africa for each of the three energy sources in 2009 and 2018, respectively. As is shown below, the Chinese are also significantly involved in both the solar PV investments – which surpassed investments in hydro-power for the first time in 2019 – and the wind-energy sector, which is forecast to grow rapidly in sub-Saharan Africa, in particular in countries with high altitudes or locations at some distance from the equator (IEA, 2016, 2020). However, there are no data sources which can give a complete picture of the relative degrees of Chinese involvement across the three technologies (Shen, 2020). The rest of this section examines how different Chinese actors have contributed to the growth of wind, solar, and hydropower projects, with a particular emphasis on **(i) financial institutions, (ii) EPC contractors, and (iii) technology providers.**

## I. Financial institutions

The Export-Import Bank of China is by far the largest investor in projects built by Chinese contractors when it comes to financial capital flows in renewable energy from China to Africa; it finances over 60% of the projects examined in the IEA (2016). Export credits and preferential loans given to project developers form the foundation of the primary investment model. Commercial loans, grants, and direct equity-based investments are also offered, especially by the financial institutions included in Table 4.

More than 85 China-financed hydro-power projects are located in Africa (International Rivers, 2019). Chinese investment in the Bui hydro dam in Ghana, to be discussed later, amounted to USD 622 million, which comprised USD 60 million from the government of Ghana, with the remaining project costs being provided by the China Exim Bank in the form of a concessional loan of USD 263.5 million and a buyer's credit of USD 298.5 million (Hensengerth, 2018). Chinese investors are involved in a number of wind-power projects in the pipeline in Djibouti, South Africa, Kenya and Tanzania (Pike, 2018; Yu, 2019). The Adama wind project in Ethiopia was financed through credit financing provided by China Exim Bank, the total project costs amounting to USD 460 million; the plant has been constructed by the Hydro-China Corporation, a subsidiary of Power-china (Chen, 2018). A number of solar-power plants are currently being constructed or are in operation that involve Chinese investors. The Garissa plant (55 MW) in Kenya borrowed USD 135.7 million from Exim Bank of China (Energy News, 2019).

Green energy infrastructure projects are integrated in transnational investment-production complexes, where financial institutions play a significant role. As part of finance agreements, these institutions may stipulate "foreign content requirements" involving Chinese EPC and technology providers.

## II. EPC contractors

Table 4 offers examples of EPC contractors for all three technologies. The majority of Chinese investors in renewable energy projects in sub-Saharan Africa are usually large state-owned enterprises (SOEs): 90% of the power projects examined in IEA (2016) are contracted and built by Chinese SOEs, including the State Grid Corporation, with the remaining 10% being built by private Chinese developers with expertise in large-scale energy-related infrastructure, construction, and civil engineering projects.

In the area of hydro-power projects in sub-Saharan Africa, prominent Chinese EPC contractors include leading Chinese dam builders, such as Sinohydro (also known as Power China) and the China Three Gorges Corporation. These Chinese dam-builders are internationally renowned for their hydro-power engineering skills and expertise (Kirchherr and Matthews, 2018). The Bui dam was built and operated by Sinohydro under an EPC turnkey contract, and it began operations in 2013. More and more prominent Chinese EPC contractors have been involved in windpower projects built in sub-Saharan Africa, including South Africa, Kenya, and Ethiopia. In the past, leading Chinese wind turbine suppliers, like Goldwind and Sinovel, have also operated as EPC contractors. Hydro-China was the EPC contractor for the Adama wind-power project in Ethiopia. In solar PV, Chinese companies were typically hired as suppliers and technology providers rather than as EPC contractors, but this is starting to change as grid-scale projects have grown. The Garissa project was built by the Chinese EPC contractor China Jiangxi Corporation for International Economic and Technical Cooperation (CJIC).

EPC plays a key role in choosing technology providers because, as previously stated, Chinese developers are in charge of every part of the project under EPC contracts, from the preliminary feasibility phase through plant engineering, component and related service subcontracting, and the plant's final commissioning.

### III. Technology providers

Chinese technology-producing enterprises, including those listed in Table 3, have been expanding into sub-Saharan Africa due to high competition in the US and European markets and a saturated domestic market (Shen, 2020). The variations in China's exports of renewable energy technology to sub-Saharan Africa over two five-year periods are displayed in Table 5, which uses the most recent statistics. Since 2010, exports in each of the three sectors have increased significantly.

**Table 5**

Exports of hydro, wind and solar equipment from China to Africa 2006–2016 (USD million).

| | 2006–2010 | 2011–2016 | Total |
|---|---|---|---|
| Hydro | 2.647 | 9.824 | 12.471 |
| Wind | 1.807 | 532.189 | 533.996 |
| Solar | 41.706 | 393.058 | 434.764 |
| Total | 46.160 | 935.071 | 981.231 |

***Source: author's own elaboration based on COMTRADE (HS codes: 841011, 841012, 841013, 850231 and 854140). *Export of hydraulic turbines and water wheels from China to Africa.***

Because core technology only makes up a small portion of the total capital investment in hydro projects, hydro technology imports and exports are comparatively low when compared to wind and solar. But compared to the first five years, commerce between China and Africa in hydrotechnologies, such as turbines, more than tripled in the second five years. However, this gain pales in comparison to the exponential growth of solar and wind. These figures demonstrate how recent the trade of renewable energy from China to Africa is, as well as how rapidly it is expanding. The export of hydro-power turbines from China to Africa is closely connected to specific hydro-power projects constructed in various countries in sub-Saharan Africa over time (IEA, 2016). The Bui dam project used Francis turbines produced by Alstom in China. Similarly, an increasing number of leading Chinese wind-turbine suppliers have been involved in wind-power projects constructed in sub-Saharan Africa. The recently constructed Lake Turkana project (310 MW), Africa's largest, makes use of wind turbines produced by the Danish firm Vestas in its Chinese factory, while the Adama project in Ethiopia used wind turbines from Goldwind and Sany. In the area of solar PV, an even larger number of Chinese companies have supplied solar panels and modules to a number of large-scale solar projects in Africa (Baker and Sovacool, 2017; Shen and Power, 2016). The Garissa project made use of solar panels supplied by Jinko Solar and BYD. The prominence of these Chinese companies is a reflection of China's role as the world's largest manufacturer of solar panels and the highly export-oriented nature of the industry (Lema et al., 2018).

To summarize, China's growing influence in sub-Saharan Africa's renewable energy sector is evident in all three of the sub-sectors examined in this article. Chinese actors, including investors, EPC turnkey contactors, and technology suppliers, are in charge of providing crucial financial and technological resources for a variety of renewable energy projects in the region. It's interesting to note that Chinese investors and contactors frequently supply projects on a turnkey basis delivered as a bundled package that includes a significant representation of Chinese investors, engineering firms, and technology suppliers. As a result, a picture of growing Chinese market share and a dominant pattern of full package provision emerges.

The nature of China's funding-support rules, which state that investors are only eligible for export credits if the equipment utilized is built in China, may have contributed to the creation of this Chinese model. Because of the predominance of state-owned firms and the packaged nature of the projects, the Chinese version of this model differs greatly from the classic Western "tied-aid" approach to development cooperation.

## 3.2. ENHANCEMENT OF CHINA-AFRICA COOPERATION IN THE RENEWABLE ENERGY SECTOR

In many parts of Africa, having access to sustainable and reasonably priced power is essential to growth. However, despite improvements in electricity access, non-hydropower renewable energy sources continue to make up a minor portion of the total. At the same time, Africa's renewable energy has not been fully utilized by China, the leader in solar energy technologies. Combining insights from recent webinars and research, Africa's access to and supply of reasonably priced and sustainable energy could be improved through China-Africa collaboration on renewable energy. Among the suggestions made to Chinese and African companies and policymakers is the implementation of open, competitive, and locally inclusive energy consumption and purchase systems.

Therefore, there are some key notes that will listed below:

- In Africa, access to electricity has increased during the last five years, but investment is decreasing, in part because of the COVID-19 pandemic.
- Through productive collaboration with China, a global leader in renewable energy, obstacles to the adoption of renewable energy in Africa could be addressed.
- There would be advantages for both parties. Because of its abundant supply of renewable energy sources, Africa offers unrealized market potential. Better access to sustainable and reasonably priced electricity as well as technological transfer would be advantageous to Africans everywhere.
- Additionally, it would help achieve the SDGs for access to power and climate change at the national and international levels.
- However, a more open and inclusive governance framework needs to be put in place if local communities are to gain.

Generally, China–Africa cooperation on renewable energy could lead to improvements in access to and supply of affordable and sustainable energy.

## 3.3. THE CHALLENGES OF RENEWABLE ELECTRICITY SUPPLY IN AFRICA

Africa has many renewable energy resources, but not enough of them are being used to power the continent's expanding economies and population; at least 579 million people lack access to electricity at the moment. Even among people who have grid access to power, supply is frequently erratic because of subpar transmission and distribution networks, which drives up costs for individuals and businesses. Though there has been significant progress in improving access and increasing spending, investment has decreased by about 30% after the Covid-19 pandemic. This poses a threat to undo the advancements made in expanding access to power throughout Africa.

Numerous African nations and the African Union have made improving access to electricity through energy supply a priority in order to boost economic growth, raise living standards, and maintain environmental sustainability. At the same time, the goal is to fulfill international obligations, such as SDG 7: Ensure that everyone has access to modern, affordable, dependable, and sustainable energy, and the Paris Agreement's goal of keeping global warming well below 2°C.

### 3.4. THE POTENTIAL OPPORTUNITIES OF GLOBAL COORPERATION

China is the market leader in the renewable energy sector worldwide, especially in the solar photovoltaic (PV) space. Eight of the top 10 global suppliers of solar panels are Chinese, demonstrating its unmatched capacity for solar panel manufacture. In 2019, its domestic annual installation on solar capacity exceeded 30 gigawatts. Nevertheless, there is still a lack of Chinese investment and exports to the African renewable energy industry. The usage of renewable energy sources like solar and wind accounts for less than 5% of Chinese energy projects in Africa.

More generally, China is coming under more and more pressure to advance cleaner energy alternatives abroad, especially through the massive Belt and Road Initiative (BRI) geopolitical initiative. Guidelines for creating a green BRI were announced by Chinese ministries in 2017, under the direction of the recently reorganized and empowered Ministry of Ecology and Environment. Though it's uncertain how such ambitious policy goals would be carried out, this was the first time an official position was made that was obviously different from the present high-carbon paradigm. Following it, President Xi Jinping declared that China would become carbon neutral by 2060.

China is becoming more involved in renewable energy in sub-Saharan Africa. As an illustration, the China–Africa Renewable Energy Cooperation and Innovation Alliance and the Africa Renewable Energy Initiative (AREI) have inked a Memorandum of Understanding to collaborate on the production of renewable energy in Africa in order to fight climate change and advance sustainable development. More people agree that it's critical that Chinese financial institutions and businesses operate in accordance with these objectives.

## 3.5. BASIC BARRIERS TO SUCCESS AND KEY POLICY RECOMMENDATIONS.

The following are some barriers to Chinese and African collaboration in renewable energy:

- The amount of debt owed by African government treasuries and utilities;
- When it comes to policy message, many African nations do not prioritize the implementation of renewable energy;
- China's complex and disjointed method for overseeing foreign energy operations;
- Instead of increasing capability, Chinese actors typically concentrate on obtaining certain projects;
- minimal or nonexistent openness in the procedures for project approval and administrative roadblocks (inconsistencies and complexity of regulatory requirements);
- African private sector participation is minimal, and technological capabilities are also lacking; and
- Inadequate consultation and involvement of stakeholders between Chinese companies and local entities.

Below is a full explanation of the barriers to success:

- **The amount of debt owed by African government treasuries and utilities:**

Even though the governments of many sub-Saharan African nations are heavily indebted, they took out additional loans for significant energy infrastructure projects. African government-sponsored proposals have generally been preferred by Chinese businesses over open renewable energy procurement, which frequently excludes smaller (often mini-grid and off-grid) projects with greater electricity access benefits, especially in rural areas. Furthermore, Chinese renewable energy firms are less compatible with models of competitive energy procurement that incorporate project finance agreements. This indicates that Chinese state-owned enterprises and lenders are less receptive to different project delivery and funding approaches for renewable energy initiatives. Therefore, the ability of Chinese businesses to fund renewable energy initiatives is extremely dependent on the state of government debt in their main African partners.

- **When it comes to policy message, many African nations do not prioritize the implementation of renewable energy:**

Investor confidence to develop long-term plans may be jeopardized if policy statements are unclear and do not clearly indicate that the implementation of renewable energy would be prioritized.

A related issue is the high transaction costs brought on by the bureaucracy involved in project approvals. Energy access, jobs, knowledge transfer, and industrial growth are just a few of the advantages that renewable energy projects can offer, but completing all of these in a single project or program can be challenging. To effectively inform investors and enhance the administration of project proposals, governments must establish clear policy priorities.

- **China's complex and disjointed method for overseeing foreign energy operations:**

There is a cost associated with coordinating when multiple important ministries are engaged. Further discriminating against smaller renewable energy projects in comparison to massive hydroelectric, coal-fired, or nuclear power plants is the tendency for larger projects with greater political attention to receive permission more rapidly.

- **Instead of increasing capability, Chinese actors typically concentrate on obtaining certain projects:**

Many African nations are having a difficult time changing their energy systems, and there is a pressing need to improve capacity building for a sustainable energy transition. Thus far, Chinese public and commercial actors have contributed little in the way of ideas to capacity building initiatives. Instead of being a political endeavor spearheaded by the state, China's involvement in Africa's energy sector is mostly economic in nature and is spearheaded by individual Chinese businesses.

- **Inadequate consultation and involvement of stakeholders between Chinese companies and local entities:**

When it comes to project execution, the majority of Chinese state-owned businesses are incredibly effective and practical. Their first priority is to complete projects on schedule, but they frequently undervalue the significance of cultivating positive community ties. Therefore, the interaction between Chinese enterprises and local communities is typically project-based, disorganized, and primarily dependent on local agents or well-connected individuals. Local employment frequently consists of low-skilled or semi-skilled positions, with employees having no formal contracts or less formal agreements and no guarantees regarding their jobs. Chinese construction crews frequently reside on other properties, which results in little interaction with the surrounding populations.

Particularly since many of the ensuing energy projects do not supply electricity to neighboring villages, this may cause conflict. Discontent among the local community is becoming a significant contributing cause to the postponement or even rejection of renewable energy projects.

- **Focusing within the larger framework of several policy domains and sustainable development trajectories is a key policy problem for China and its African allies:**

The major goal of energy programs, as seen from the standpoint of people-centered development, is to make sure that the pro-poor objectives of the many policy strands of energy access, renewable energy, green growth, and climate mitigation are mainstreamed and given priority.

Furthermore, the basic key suggestions to the enhancement of China-Africa cooperation in the renewable energy sector are been listed below which are offered to provide greater accessibility to reasonably priced and environmentally friendly electricity.

**From an African perspective:**

- For the adoption of renewable energy, governments should establish precise implementation roadmaps together with attainable policy targets.
- Reducing the transaction costs associated with the development of renewable energy projects requires institutional reform. For instance, more Chinese businesses might participate in the open bidding process if procurement procedures are standardized.
- In particular, when negotiating with Chinese stakeholders, give green energy projects and energy access a priority both during and after the COVID-19 pandemic.

- In addition to creating strategies to boost indigenous expertise, like through technology transfer and skilled worker involvement, African governments should support domestic industry in the renewable sector.

**From a Chinese perspective:**

- It is imperative that Chinese banks and state enterprises provide more adaptable and creative tools to assist smaller-scale renewable energy initiatives, especially in Africa's rural areas. It should be encouraged for private businesses to investigate African markets.
- The regulators and utilities in the African energy industry should be included in the capacity building that Chinese authorities fund. Focusing efforts to create sustainable power projects in accordance with national strategy would be made easier with a greater grasp of the host countries' goals for renewable energy.
- To make sure that projects satisfy local demands, Chinese authorities and businesses should place a high priority on interacting with local people. The energy requirements of the local community and socioeconomic circumstances must guide the selection and screening of projects.

**Overall:**

- Significant institutional changes to current governance models are necessary to increase investment in renewable energy in Africa.
- Other initiatives, such as policy synchronization across the designated sectors of the China-Africa agreement, are required from both Chinese and African partners.
- In African countries, a more robust Chinese commitment to "bottom-up" local participation, community discourse, and cooperation will guarantee that involvement encompasses not only government-level involvement but also community knowledge and interests.

# CHAPTER 4

## RESEARCH METHODOLOGY AND STUDY AREA

## 4.1. THE KEY FACTOR AND INDICATORS FROM INSIGHTS OF THE CHINESE PROJECT

This chapter of the research project focuses on the primary data to examine the key factors and indicators developed for the analysis in (Chapter 2). Three sub-sections illustrate each of the case study projects in turn. Table 6 provides an overview of the key actors in these three projects across both the stage of infrastructure delivery (engineering, procurement, construction and various sub-tasks) and the stage of service delivery (operation, maintenance and distribution). These are preceded by an initiation stage focusing on entrepreneurial development and the negotiation stage, which is important because it defines the nature and scope of the subsequent steps.

### 4.1.1. THE ADAMA WIND PROJECT

The Adama wind-power project was planned and built in two stages by a joint venture between Ethiopian Electricity Power (EEP), the project owner, and the Chinese construction firm CGCOC group and turn-key contractor Hydro China. Therefore, all ancillary and civil work as well as the project's design, production, supply, installation, testing, and commissioning were covered under the EPC contract. 51 MW of wind power was installed during the first phase, which was completed in 2012. There were 102 turbines installed in total for the second phase, Adama II. In 2015, the 153 MW project came online.

The types of jobs created by the Adama project are directly related to the finance arrangements, which mandated the use of Chinese technology in the project.

Hydro China-CGCOC held the turnkey contract for the project, which covered the majority of the value chain from design and construction to handover training. Hydro China was in charge of local job creation in project construction, which totaled a thousand across the two phases of the project, compared to around four hundred Chinese personnel. The contract between EEP and Hydro China stated that unskilled labour should be recruited locally, and that hiring personnel and skilled labor with the requisite qualifications and experiences from sources within Ethiopia was to be promoted. However, the large number of Chinese employees involved during this phase suggests that the job types varied and that project management was to a large degree carried out by Chinese nationals. The key project management personnel included approximately thirteen Chinese staff for phase II, ten of whom had already worked on phase I.

Hydro-China held several information sessions and seminars to educate local residents on the impacts of wind farms. Local content was limited to the minimum involvement of local firms in the supply of construction materials, primarily concrete, while the state-owned shipping company was involved in the transportation of wind-turbine components. Additionally, all imported equipment, materials, and construction equipment were exempt from customs duties, value added tax, and additional taxes. Additionally, local communities showed minimal involvement in deciding compensation for the temporary and permanent loss of farmland in order to build the wind farms and the necessary access roads; aside from the access roads and water pumps, other social development projects were not deemed necessary.

All of the project's permanent equipment was sourced and imported from Chinese companies as "black-box" components, such as the unit transformer, 33KV cabinet, main transformer, circuit breaker, grounding transformer, SCADA system, and communication equipment. This limited local learning in terms of technological learning. Hydro-China and CGCOCC independently developed the investment model, designs, and blueprints for the project.

However, a team of 17 university employees was engaged by EEP to monitor implementation of the project during the construction stage and administer the contract. These employees were engaged to carry out a number of supervisory tasks, including reviewing micro-siting and layout designs, supervising the civil infrastructure, construction and erection of the wind turbines, controlling environmental activities, and preparing project manuals and reports, among others. The university consultancy arrangement was the result of a national strategy to involve universities in projects in order to facilitate technology transfers and capacity-building.

**Table 6**

**Overview of the projects: actors and roles**

| Capacity and ownership | | Adama | Bui | Garissa |
|---|---|---|---|---|
| Ownership and Capacity | - Owner/sponsor<br>- Energy source<br>- Size<br>- Cost | - Ethiopian Electricity Power<br>- Wind<br>- 204 MW<br>- USD 462 million | - Bui Power Authority<br>- Hydro<br>- 400 MW<br>- USD 560 million | - Kenya Rural Electrification Authority<br>- Solar PV<br>- 55 MW<br>- USD 140 million |
| Infrastructure delivery | - EPC and project management<br>- Finance | - Hydro-China and CGC Overseas Construction Group<br>- Export-Import Bank of China (85%) and Government of Ethiopia (15%) | - Sino Hydro<br>- Export-Import Bank of China (89%) and Government of Ghana (11%) | - China Jiangxi Corporation for International Economic and Technical Cooperation (CJIC)<br>- Export-Import Bank of China (100%) |
| | - Front-end and detailed engineering<br>- Core technology supply | - Hydro-China and CGC Overseas Construction Group<br>- Gold-wind (China) and Sany (China) | - Coyne et Bellier (France) and Sino Hydro<br>- Produced in China by Alstom (France) | - CJIC and Maknes Consulting<br>- JinkoSolar (China) and BYD (China) |

| | | | | |
|---|---|---|---|---|
| Service delivery | - Electricity Distribution<br>- Plant operation<br>- Plant Maintenance | - Ethiopian Electric Services (EES)<br>- Ethiopian Electricity Power<br>- Ethiopian Electricity Power | - ECG/Gridco<br>- Bui Power Authority<br>- Sino Hydro | - Kenya Power and Lighting Company<br>- Kenya Electricity Generating Company and CJIC<br>- KECG |

The EPC contract specified that EEP staff would be trained in the operation and maintenance (O&M) of the turbines, including one month of training in China and a twelve-day training course in Ethiopia in each phase. However, the training was reported to have entailed linguistic challenges in the translations. Furthermore, the project had a relatively short handover period from Sany (as technology suppliers in phase II) and Hydro-China to EEP for the operation and maintenance of the project, with only an O&M support agreement, rather than a service agreement of five years or more, which is the standard practice in the industry. Overall, the project owner's knowledge accumulation was focused on O&M related, while the university consultancy was specifically tasked with acquiring knowledge in project management, the implementation of construction contracts and ultimately building capacity for the manufacture of the components of wind-power technologies.

In summary, the Adama project is a case of medium co-benefit creation, with moderate local job creation in low-skilled construction and O&M, some local sourcing of peripheral services, and the critical involvement of actors in the local knowledge system. There was some technological learning, but it was still rather restricted. Most learning was confined to service delivery domains, with little to no learning in the infrastructure delivery domain. The main explanation for the economic co-benefits observed here are to be found in the semi-strategic stance adopted by the Ethiopian government, with a deliberate and explicit effort to obtain useful knowledge from the project implementation process. The nature of the technology adopted and the absence of a corresponding local supply base meant that there were few possibilities for local inclusion in the manufacturing chain, but there was a possibility for further inclusion in services, such as plant construction, turbine assembly and installation. However, the project was undertaken mainly as a 'bundled' model with end-to-end services delivered by the Chinese consortium. This model was chosen through non-competitive and direct negotiations between the local government and the Chinese developers. Policy was the most decisive factor in securing some benefits, but it was not extended beyond involving key knowledge actors, so that further potential economic activities were not localised.

#### 4.1.1.1. CHINA ETHIOPIA COOPERATION FOR WIND ENERGY DEVELOPMENT

A number of policies, plans, and initiatives have been created and put into action by the Ethiopian government in order to establish an appropriate framework for inclusive green development (FDRE, 2011). In order to encourage sustainable economic growth that is resistant to environmental and climate shocks, the state government implemented the Climate-Resilient Green Economy policy (EFDR, 2019). Additionally, improving productivity growth and sustainable resource usage can give businesses a competitive edge (Berhanu Jabasingh and Kifile, 2017), and the possible conflict between combating climate change and economic growth can be resolved (Padam et al., 2018). In order to implement the green economy growth strategy, the government has begun developing environmentally friendly infrastructure based on renewable energy sources, especially to meet growing energy demands (FDRE, 2011). In order to eradicate poverty and promote economic growth and development, it is thought that the nation's increasing energy demand must be met (Mondal et al., 2018).

Ethiopia has challenges with access to electricity and infrastructural development, same like the rest of Sub-Saharan Africa (Azeb, 2015). Due to the country's economic expansion, the need for energy has been steadily rising. Ethiopia's overall energy consumption increased by 30% between 2010 and 2018 (EEPCo, 2022) and is currently high, whilst the country's demand for electricity increased by 130% during that time. Electricity production is expected to rise by 100% to 300% between 2018 and 2030 as a result of this rising demand (ibid.). This prediction will be met by investigating alternative means of supplying a sufficient supply of energy rather than solely relying on the growth of hydropower. As part of a larger strategy to close the gaps in power infrastructure, the Ethiopian government intended to create alternative energy sources in anticipation of the difficulties posed by the lack and scarcity of electrical infrastructure (Chen, 2018).

Ethiopia had expressed interest in creating non-hydro renewables due to the erratic nature of hydropower-based generation after participating in the 2001 Solar and Wind Energy Resource Assessment (SWERA) meeting organized by the United Nations Environment Program and Global Environment Facility (Padam et al., 2018). According to the researcher (Chiyemura, 2020), after SWERA was finished, the Ethiopian government asked the German Society for International Cooperation (GIZ) to carry out suitability studies for the construction of wind farms, and 11 locations were determined to be viable. From these 11, three locations—Harena, Ashegoda, and Nazareth—were the subject of feasibility studies. According to HCC (2012), the three locations showed adequate potential for wind energy, with yearly averages of 6.86 m/s, 8.50 m/s, and 9.36 m/s, respectively. While this was happening, the Ethiopian government hired HydroChina to complete a Wind and Solar Energy Master Plan for Ethiopia, according to the author (Chen, 2018). In this plan, they found that Ethiopia had a 3.03 TW wind resource reserve, of which 1.35 TW could be constructed. Furthermore, according to MoWIE (2019), Ethiopia has 51 possible locations for wind farms with a combined installed capacity of 6.72 GW.

According to MoWIE (2019), the completion of the SWERA and HydroChina Master Plan studies gave the Ethiopian government access to accurate, verifiable, and reliable data, supporting its aggressive wind and solar energy development. The government of Ethiopia proposed to build eight wind farms during GTP1 in 2010 (MOFED, 2010). Meanwhile, it was recommended that in order to secure funds for the project, the Ministry of Finance and Economic Cooperation's (MoFECC) Ethiopia-China Development Cooperation Directorate get in touch with the Chinese Export and Import Bank (CEXIM Bank) (ibid.). The creation of the project was selected by the Chinese government since they do not require aid with governmental transformation beforehand. According to Chen (2018), the two wind farms were entirely financed by Engineering Procurement and Construction plus financing agreements, with Adama 2 obtaining a concessional loan and Adama 1 obtaining a favorable export buyers' credit. These projects were carried out so that Adam 1 (which produced 51 MW of power) was started in 2011 and finished in 2012; Adam 2 (which had a capacity of 153 MW) was then started in 2013 and finished in 2015 after three years (MoWIE, 2019). 85% of the $522 million project budget was provided by the Chinese government, with the Ethiopian government contributing the remaining

15%. According to Power-China (2016), the farms are the first clean energy project constructed by Chinese enterprises in Africa and account for almost 15% of all electric energy supplied on-grid.

#### **4.1.1.2. SOCIAL AND ENVIRONMENTAL CONTRIBUTION OF THE WIND ENERGY PROJECT COOPERATION.**

By boosting infrastructure, promoting sustainable development, and improving lives, the Adama Wind Project has significantly impacted Ethiopian society. Its main contributions to society are as follows:

1. **Greater Access to Electricity:**

Gives homes, businesses, schools, and hospitals clean, reliable power. supports electrifying rural areas to enhance healthcare, education, and living standards. makes energy consumption safer and more sustainable by reducing need on biomass and kerosene.

2. **Skill Development and Job Creation:**

During construction and continuing maintenance, thousands of jobs were created. And trained Ethiopian engineers, technicians, and employees in the field of renewable energy and this as strengthened Ethiopia's ability to autonomously operate wind energy projects by aiding in the transfer of technology.

**3. Infrastructure Development:**

The Adama region's road networks have been improved, enabling trade and transit and also improved local infrastructure, which has a knock-on effect on agriculture and business connecting to improving public services by guaranteeing a steady supply of electricity, such as schools and medical facilities.

4. **Encouragement of Economic Growth:**

Increased Ethiopia's standing as a pioneer in renewable energy and drew in international investment which help to promote the expansion of regional companies, particularly in Adama and the neighboring regions. Also decrease the power interruptions that impact businesses and job security, so aiding in the stabilization of Ethiopia's energy industry.

5. **Benefits to the environment and human health:**

Less indoor air pollution due to a decreased need on firewood and kerosene lamps which also greatly reduced greenhouse gas emissions, which helped mitigate climate change. Also supported sustainable growth in line with the Climate Resilient Green Economy Strategy (CRGE) of Ethiopia.

6. **Community Awareness and Engagement:**

Involved local communities in environmental assessments and project planning which help to increased acceptance of green technologies by educating people about the advantages of renewable energy and also promoting young research and education in sustainability and wind energy.

Therefore, The Adama Wind Project serves as a catalyst for social and economic change in addition to being a power producing project. By enhancing energy accessibility, generating employment opportunities, and promoting sustainability, the initiative advances Ethiopia's goal of a self-sufficient, environmentally friendly economy.

According to TofuWolka and Oldeamanuel (2022), environmental development is the process that gives us the authority to safeguard natural resources from pollution and to maintain and preserve them. Greenhouse gas emissions may noticeably decline as a result of the transition to a green economy. By 2030, the global energy intensity, measured in millions of tons of oil per unit of GDP, would have decreased by 36% if 2% of GDP were allocated to important green economy sectors and more than half of that investment was focused on increasing energy efficiency and expanding the production and use of renewable energy resources, according to IEA research (IEA, 2022). Similarly, the investment scenario (Khanfar, 2014) calls for an increase in energy-related carbon dioxide emissions from 30.6 GT in 2010 to 20.0 GT in 2050. Consequently, investment in the low-carbon economy can significantly improve the problems it presents (Zazykina and Bukova, 2021).

In addition, MEA (2005) noted that the sustainable use of ecosystem services is one of the additional environmental advantages that may be obtained using a green economy. Studies conducted for the UNEP report on the green economy (UNEP, 2011) show how significant advancements in this goal can be made by putting policies in place aimed at controlling the demand for ecosystem services that are utilized, along with expenditures to increase the supply of those services. This is because it is a more cost-effective and environmentally friendly method that supports green growth by improving soil fertility (Ferede, 2020), water accessibility (TofuWolka and Woldeamanuel, 2022), and carbon emission storage services (Zazykina and Bukova, 2021). Given that access to electricity and other contemporary energy sources is still restricted in Africa, the implications of green economy development portfolios and routes for sustainable development are especially significant there (Ouedraogo, 2017). According to Blimpo and Cosgrove-Davies (2019), over 51% of the continent's population primarily relies on biomass for energy, which has numerous negative effects on the ecosystem, of which Ethiopia is not an exception.

Electricity only makes up 3% of Ethiopia's overall energy supply (MoWIE, 2019). The yearly per capita power usage as of 2017 (IEA, 2022) was 100 kWh per person, making it one of the lowest in the world and Africa (MoWIE, 2019; Padam et al., 2018), with only 44% of households having access to a basic electrical supply. According to AFREC (2022), Ethiopia is one of the top ten African countries in terms of the proportion of energy derived from biomass fuels. Biomass fuels accounted for over 86% of Ethiopia's total energy consumption in 2019, compared to Africa's average of 51% (IEA, 2022). At least one-third of fuelwood now comes from unsustainable forest and woodland extraction (MoFECC, 2017), which contributes to the fuelwood scarcity in a number of the country's areas (EUEI, 2013). Additionally, the excessive dependence on biomass fuel and its inappropriate use result in land degradation and deforestation, both of which have an adverse effect on the ecosystem (Yalew, 2022). Additionally, according to FDRE (2011), roughly 46% of Ethiopia's overall GHG emissions from the forestry sector are caused by fuelwood usage, which degrades forests. It also noted that the country's 730,000 hectares of forest, forests, and shrublands might be destroyed each year as a result of fuelwood usage.

Ferede (2020) reports that Ethiopia uses 105,172,465 tons of biomass fuel per year from wood products (such as round wood, branches, leaves, and twigs) and total charcoal equivalent wood. According to Kofman (2010), all wood has about the same gross calorific value per ton of dry matter when accounting for overall energy production in GJ or MWh, with conifers having 19.2 GJ/ton and broadleaves having 19.0 GJ/ton. According to Kofman's (2013) research, the moisture content of wood fuel has a significant impact on its net energy content. The author stated that in order for wood to burn satisfactorily, it must be at or below the fiber saturation point, which varies depending on the species but is normally around 25% moisture content. One can use the following calculation to determine the net calorific value per ton of broadleaves (Kofman, 2010).

$$NCV = 19(0.2164 * MC) = x\ GJ/t?$$

Where:

***MC** is for moisture content, which is stated as a percentage rather than a proportion,*

***NCV** stands for net caloric value,*

***GJ** stands for gage joule.*

According to Morketo Fekadu and Dajene (2022), Eucalyptus globulus trees are the most prevalent and fruitful fuel wood sources in Ethiopia. They burn well with a moisture level of 25% of their total weight. According to the formula created by Kofman (2010), its net calorific value per ton at this moisture content is equal to 13.59 GJ/ton (3.78 MW) by using the coefficient created for broadleaves. This figure is nearly identical to the finding of Kofman (2010), who showed that the moisture content of fuel wood determines how much of it is required to replace a typical amount of fossil fuel. Additionally, the author discovered that wood chips may provide 3.79 MW/ton of total energy at a 25% moisture level. Instead of using the coefficient designed for conifer species, we used the one created for broadleaf to calculate the NCV of eucalyptus species. The primary reason for this is that coniferous species are soft wood tree species, whereas the majority of broad-leaved species have hard wood, with eucalyptus species also being classified as hard wood species (Kofman, 2013). Based on the justification provided, the total quantity of energy that Ethiopia can produce, given its average annual fuel wood consumption of 105,172,465 tons, is predicted to be 397,551,918 MW. To put it another way, 105,172,465 tons of wood may produce 397,551,918 MW of energy if one ton of dry weight Eucalyptus globulus tree fuel wood produces 3.78 MW.

Taking into account the previously mentioned outcome of the total energy that can be produced by the annual fuel wood consumption from an environmental standpoint, it might be feasible to think of it as the number of trees or forests per hectare that can generate the stated total amount of annual fuel wood consumption. Dejenea Kidaneb and Bahirua (2018) carried out a comparative growth performance study on Eucalyptus globulus, a fast-growing tree species for fuel wood production in a highland region of Ethiopia planted at 1.5 x 1.5 m. The study revealed a 100% survival rate up to seven years of harvesting. Given the survival rate the researchers were able to achieve, 4,444 eucalyptus trees per hectare might be managed in order to provide ultimate fuel wood. Additionally, a study conducted at the same location (MorketoFekadu and Dajene, 2022) found that the average above-ground biomass (AGB) of a single Eucalyptus globulus tree at harvesting age was 87.47 kg/tree, encompassing components of stem wood, branch, leaf, and bark. According to Kofman (2013) and MorketoFekadu and Dajene (2022), if 25% of the tree's total weight is set aside as an MC for the wood to be used as fuel, the remaining 65.8 kg/tree may be the dry weight of a tree or wood that could be used as fuel wood to produce the necessary amount of energy at seven years of harvesting age. According to this calculation, the designated tree species could yield roughly 292.42 tons of fuel wood per hectare at the stated harvesting age, producing roughly 1,105.35 MW of energy. Taking into account Ethiopia's yearly fuel wood consumption of 105,172,465 tons, the total weight of fuel wood trees produced per hectare of area is predicted to be produced from 359,662.35 hectares of land. This showed that the aforementioned hectares of forest are cut down year in Ethiopia to provide fire wood.

Eucalyptus globulus trees, which have demonstrated superior performance (Dejenea Kidaneb and Bahirua, 2018) for fuel wood production, can yield 292.42 tons of fuel wood per hectare, which translates to approximately 1,105.35 MW of power generation during a seven-year period. In relation to this, the Adama wind energy project, which has 204 MW of power and a turbine output capacity factor of 30.5% (HCC, 2012), can produce 62.22 MW of energy per hour, which is anticipated to save around 16.46 tons of fuel wood each hour. This is estimated to be produced over more than 493 hectares of land, yielding 144,189.6 tons of fuel wood annually. Tropical pine and eucalyptus tree plantations have the capacity to store an average of 10 tons of carbon per hectare annually, as shown by Myers and Goreau (1991). Here, it is anticipated that 4,930 tons of carbon will be sequestered annually every 493 hectares of forest land. In this sense, as part of the growth of the green economy, the Adama wind energy project mitigates climate change and promotes environmental conservation.

### 4.1.2. THE BUI DAM HYDRO-POWER PROJECT

Construction of the Bui Dam by Sinohydro, a Chinese state owned enterprise that is the world's largest dam-builder, with a global market share of more than 50% in charge of its execution, started in 2006. The contract with Sinohydro was a turnkey or EPC contract, which meant that Sinohydro was only in charge of its construction, not also its operation. The Bui Dam, a roller compacted concrete (RCC) gravity dam in Ghana with a capacity of 400 MW, was completed in 2013, the entire dam (including turbines, powerhouse etc.) and its operation being turned over to the Bui Power Authority (BPA) upon completion of the project.

Formally, strategic oversight of the project lay with the Ghanian Ministry of Energy (MoE), the operational oversight with the Bui Power Authority (BPA). A nuanced understanding of mega-dam construction is needed to fulfil such oversight duties sufficiently (Flyvbjerg, Holm, and Buhl, 2002). However, various interviewees suggested that Sinohydro reporting to the MoE and the BPA was relatively sporadic and at times incomplete.

In respect of jobs, of the 1836 workers employed at the Bui Dam construction site, as many as 91% were Ghanians, the project thus providing 'temporary employment for roughly one out of 20 workers in the Tain District' where the project is located. On-the-ground management of the project, however, was exclusively Chinese. Informants suggested that importing relatively low-skilled construction workers from faraway China instead of hiring them locally, with only the little training then required, would increase the project's costs. Around 50 Ghanians staff, employed by BPA, are now involved in the operation and maintenance of the project.

With regard to local content, most material-processing content and associated sourcing needed for the dam, mostly concrete, were sourced locally. The exact percentage of local content going into this project is difficult to establish, but one informant estimated that at least 60% of this project consisted of local content. This high share of local content was to some extent policy-driven, as a clear local-content policy guides investment in the country. While overall local content provision was significant, it is also clear that the more sophisticated provision of products and services was retained by Sinohydro, which, for example, procured three 133 MW hydro turbines from the French company Alstom's factory in China.

In respect to technological learning, we distinguish between learning related to construction and to operation. While the construction of a large dam is a complex endeavour, with hydro-power dams completed post-2000 facing an average cost overrun of 33% and an average schedule overrun of 18%, its operation is relatively uncomplicated. BPA expected to be able to operate the dam upon its completion. However, this turned out not be the case. Sinohydro was re-engaged to ensure that major maintenance was carried out (also reported by GhanaWeb (2017)). This suggests that little technological learning took place on the Ghanian side in connection with the project's maintenance when it was constructed. Also, Sinohydro did not transfer any significant knowledge and expertise regarding the technology to the Ghanians. Deliberate knowledge transfers related mainly to operational tasks during the construction phase, with Ghanian construction workers undertaking two-week boot camps organized by Sinohydro prior to working on the construction site, as well as being given additional on-the-job training.

In summary, this is a case of low co-benefits, with employment of workers in Bui district during construction, but with little national impact. Limited technological learning took place, mostly confined to the operations part of service delivery and not including maintenance or construction, but there was a significant degree of local sourcing of construction materials. The main explanation for the identifiable economic co-benefits is the nature of the technology, where project management is highly complex, where only a few steps in infrastructure delivery in the value chain can be carried out remotely and where construction needs to be localised. However, due to the absence of independent local firms, in Ghana these steps were carried out by Chinese firms. The project contract was directly negotiated between the Ghanian government and the Chinese developers. In the absence of a strategic vision on the part of the government, the EPC's full-package provision left very little room for localisation and learning in this deal. The core insight from the Bui Dam case with regard to co-benefits from the perspective of the Ghanian stakeholders is thus that the most crucial long-term co-benefit, technological learning, was not facilitated by Sinohydro. However, those co-benefits that are frequently discussed in the popular press, namely local content, local participation and job creation, were more substantial.

#### **4.1.2.1. SOCIAL AND ENVIRONMENTAL IMPACTS OF BUI-DAM HYDRO-POWER PROJECT**

According to a 2015 report by the Environmental Justice Organizations, Liabilities and Trade, the building of the Bui Dam caused more than 1,200 Ghanaians to be forcibly relocated and flooded 21% of Bui National Park. Conflicts between host and settler populations and the destruction of ecosystems in Bui National Park are just two of the problems that the resettlement process has brought about in the local community and the environment. According to an Environmental Resource Management assessment, flooding the reservoir would not have a catastrophic effect on the natural habitat, despite worries about the dam's potential to harm nearby population. The delayed filling phase of the reservoir was able to prevent large-scale direct loss, even though the inundation processes did cause terrestrial species to drown.

Numerous scholars have studied the effects of the local residents' displacement by the Bui Dam Authority. Abrampah claims that at least three communities were uprooted during the building of the Bui Dam, and as a result, they experienced economic hardship since they were unable to reach their customary fishing grounds. As they were being forced to leave their ancestral homelands, these communities also had to redefine their own identities, among other major cultural and societal obstacles. In his analysis of the Bui Dam's downstream social effects, Owusu found resource-use disputes in seven farming and fishing communities along the Black Volta River that have not been resettled. Although the dam's construction has improved social infrastructure, he finds that the non-resettled communities have suffered from the flood of migrants and disputes over resource use.

In contrast to the dam builds at Akosombo and Kpong, the Bui Dam relocation program was more planned and executed. In contrast to the Bui Dam, which only impacted 1,216 people, the preceding two dams forced 88,000 residents to relocate completely. In accordance with the legal requirements of the "World Bank's Standard for Resettlement," the Bui Power Authority created a program for resettlement and community support that included agricultural land, two schools, one clinic, household buildings, forestry compensation, relocation grants, and a one-year income subsidy. The resettlement initiative is showing encouraging results. Roads, drainage systems, and other public infrastructure have been improved. Roads, drainage systems, and other public infrastructure have been improved. Both the communities that were resettled and those that were building the Bui Dam saw a rise in economic activity and opportunity. Alongside the population growth, there has been a significant improvement in health and sanitation.

Other studies have demonstrated that the negative environmental effects of dam projects are dependent on factors other than only the performance of Chinese businesses. Hensengerth contends that agreements with Chinese businesses are essential, as are the environmental and governance laws of the host nations. The environmental protection policies that Chinese businesses implement are jointly decided by them. Since they are still relatively new to the global market, many Chinese businesses are learning from and changing their methods to more closely resemble those of other foreign firms. Furthermore, Chinese businesses have taken the initiative to implement CSR policies after realizing that better practices could eventually result in a more competitive position for them in the global market. Enhancing its governance procedures and environmental standards was also of importance to EximBank, the project's principal investor. Brautigam notes that Chinese financial institutions, such as EximBank, are growing increasingly conscious of the changing export credit standards. Even though China is not a member of the OECD, the bank stresses that its loans "generally" adhere to the OECD Arrangement. In an interview with Brautigam in 2008, the president of EximBank claimed that senior management thought Western organizations were more reliable, hence the bank solely collaborated with them to examine environmental concerns. The bank released two environmental recommendations, one in 2007 and the other in 2004.

The nature of the project's non-bidding procedure is another issue. Through negotiations between the governments of Ghana and China, Sinohydro was chosen as the sole source for the contract. Sinohydro and the Ghanaian government inked a Memorandum of Understanding in 2005 to fund and build the Bui Dam. In 2008, the Ghanaian government and EximBank completed the loan arrangement. Hensengerth contends that international standards were applied throughout the Bui Dam project even though there was no international bidding process.In addition to hiring European firms to carry out feasibility studies in 1995 and environmental and social impact assessments (ESIAs) in 2007, the Ghanaian government also put in place environmental regulations that complied with international standards. As a result of Ghana's legal enforcement, Sinohydro and Exim Bank were subject to international norms.

As the leaders of the world's largest economies, investing nations' commitment to maintaining openness and sound governance is crucial, according to a Global Witness report. The international community has few options for disciplining them, even if they do nothing to increase transparency and accept accountability. The necessity for Chinese businesses to implement environmental protection criteria for projects abroad has also been acknowledged by the Chinese government. A set of rules for the actions and conduct of Chinese corporations with regard to environmental protection was jointly released in February 2013 by the Chinese Ministry of Commerce and the Ministry of Environmental Protection. Sinohydro is required to follow these rules because it is a sizable state-owned company that frequently conducts business abroad. Concerns have been raised by some academics over the concentration of Chinese workers in African nations. Although Chinese corporations make significant investments in Ghana, Kernen and Nam believe that there is still a lack of full localization of Chinese SOEs in Ghana. 36% Although the business employs local management personnel, they are primarily used for external operations like sales and human resources in an effort to improve the company's reputation for interacting with the community. The degree of localization of Chinese management can be limited, as demonstrated by this.

But according to Han, during the 2009–2013 Bui Dam construction phase, 2,600 people were needed for 65 different sorts of occupations, and the number of Chinese workers never surpassed 400. Approximately one hundred of them were Pakistanis working in specialized jobs like operating machines. Before construction began, the majority of the Ghanaian laborers on the Bui Dam site lacked much experience. Following employment, the Ghanaians underwent a three-phase training program. According to Kernen and Lam, during onsite work, more experienced Chinese workers frequently supervising, mentoring, and working in groups with local workers for a while until the Ghanaian workers fully understood the methods and abilities for free work.In addition to creating a lot of job opportunities in the neighborhood, the building project gave local workers access to certain technical skills. Furthermore, Han claims that because of the high prevalence of waterborne illnesses like malaria and the dearth of medical services in the area, the Bui Dam project management office established a medical center on site. Chinese Communist Party committees also planned on-site leisure events and donated to nearby communities and educational institutions in an effort to strengthen links between residents and expats.However, two strikes took place in 2008 and 2013 as a result of risk to health and safety, low pay, working overtime, and not having guaranteed leave. Thus, in 2009, a local labor union was formed. Sinohydro also inked a deal with the Trades Union Congress of Ghana, which called for a better understanding of the rights and responsibilities of both employees and managers.

The majority of current research on the Bui Dam only addresses the negative effects on the environment and society. Its potential advantages in expanding access to energy, creating jobs, and enhancing health and education have seldom been discussed in the literature.

### 4.1.3. THE GARISSA SOLAR PV PROJECT

The Garissa Solar PV project is the first grid-connected solar PV project in Kenya, with a capacity of 50 MW. It was conceived in 2012 by the government of China and the Jiangxi Province representatives, along with the government of Kenya and the representatives of Kenya's Ministry of Energy. The lead project developer (in particular, the Jiangxi Province representatives) also facilitated securing the full project finance via China's Exim bank, which was provided as a concessional loan, with low interest rates and a long maturity period. The total investment for the project was USD 135 million. The project is administered and owned by the Rural Electrification and Renewable Energy Corporation (REREC, formerly REA), a government organization spearheading renewable energy development along with rural electrification in Kenya. It was commissioned in 2016, after prolonged negotiations with Kenya Power (KPLC) on the 25-year power-purchase agreement. While there is a feed-in tariff in place in Kenya to attract private investment and standardize tariffs, this was circumvented, and direct negotiations were used instead.

The choice of technology suppliers for the Garissa project was determined by the tied financing agreement, which mandated the use of Chinese technology. The Jiangxi Province representatives recruited their own state-owned enterprise, the China Jiangxi Corporation for International Economic and Technical Cooperation (CJIC), as the lead EPC and signed a contract with Jinko Solar to supply panels, and with Byd for inverters. CJIC also subcontracted two Chinese companies for project design and civil works. After the project's completion, there was a brief handover period from

CJIC for the O&M, with a service agreement of two years, to the Kenya Electricity Generation Company (KenGen), responsible for undertaking O&M at the plant and contracted by REREC.

While there was no explicit strategy, the priority for local jobs was subject to a verbal agreement between REREC and CJIC. The overall project management was carried out by Chinese nationals, while nearly 85% of the workers employed during the project's construction were Kenyan nationals. However, most of them were hired on a casual basis, without formal contracts and associated benefits. Also, only limited efforts were made to enable skill-sharing, training low-skilled workers for semi-skilled tasks or engaging local universities or vocational training institutes in practical knowledge acquisition regarding project designing or installation. During the construction period, some 300 to 350 Kenyan workers were employed. Of this, a majority took on low-skill tasks as carpenters, masons, drivers, manual lifters and security guards, and they were involved in developing internal project roads, constructing the perimeter wall and office buildings, lifting solar panels and performing various other manual tasks. The rest were engaged in semi-skilled tasks, including the installation of solar panels, electrical work and steel work. In this period, nearly 75 Chinese employees were engaged in preparing steel structures, supervising tasks, operating JCB machines and performing various electrical tasks. During the operational phase, nine O&M engineers will be employed on a contract basis, of whom five are Kenyan nationals and four are Chinese, forming an all-male team working in a similar capacity.

The bundling of finance with an EPC contract left relatively limited scope for local content. The sub-contractors included mainly Chinese companies for project design, procurement and installation of solar panels. For civil works, a local Kenyan company was sub-contracted to provide workers during the construction phase. While Kenya has a sizeable number of solar PV companies, they are focused mainly on off-grid systems and small-scale PV installations (below 1 MW). A few companies are gradually scaling up in the hope of obtaining sub-EPC contracts (i.e. for construction work) for large-scale PV projects, but there are still limitations pertaining to project design, sizing systems optimally and handling various O&M tasks.

In terms of local technological learning, there was only a limited transfer of core technological knowledge, since all the permanent equipment for the project was imported as embodied knowledge from China, including 200,000 solar panels, other associated equipment, electrical equipment, including transformers and inverters, the control system and construction tools. Some construction equipment was sourced locally in Kenya, including electrical cabinet boxes, switch boxes, circuit breakers and a few construction materials. While core technological learning was limited, there was learning in other areas, including 'systems' design and operations. REREC engaged a Kenyan firm, Maknes Consulting Engineers, to oversee technical activities in the project. Maknes played a supportive role in reviewing the project drawings and O&M manuals, supervising the installation work, and overseeing technical progress. Reportedly, the tasks carried out by Maknes in the Garissa project were similar to those undertaken in other projects, albeit not on this scale. In other words, local knowledge acquisition regarding large-scale PV was deliberately designed into the project, which may be relevant to future projects.

To summarise, this is a case of low co-benefits. Although local job-creation was significant (of the three projects, the highest per megawatt installed), local equipment provision and skills and knowledge transfer were limited and peripheral. Although one local engineering firm became involved in the infrastructure delivery process, gaining experience relevant to project execution, local learning was mainly confined to O&M. The main explanation for the limited economic co-benefits that were observed in this case are to be found in the institutional arrangements surrounding the project, with limited strategic intent evoked by local policy-makers in relation to its organisation. The project was directly negotiated and involved a consortium model involving Chinese firms, contractors and financiers with limited involvement by local actors. Although local solar firms could arguably have taken responsibility for parts of the project's construction, this was precluded by the 'tied finance' underpinning the project.

#### 4.1.3.1. THE SOCIAL AND ENVIRONMENTAL CONTRIBUTIONS OF THE GARISSA SOLAR PV PROJECT.

One of Africa's biggest solar power plants, the Garissa Solar PV Project in Kenya, has significantly improved the environment and society since it was put into service in 2018. An outline of its effects is provided below:

**ENVIRONMENTAL CONTRIBUTIONS:**

1. **Cutbacks on Greenhouse Gas Emissions:**

This help produces energy that is clean and renewable, lowering dependency on fossil fuels and also keeping over 43,000 tons of $CO_2$ from being released each year, helping Kenya achieve its climate goals. The aids Kenya's energy transition to green energy, in line with its Vision 2030 and international climate pledges.

2. **Preserving Natural resources:**

This is actually one of the contributions to the environments because it doesn't require water, unlike hydropower, it's perfect for desert areas like Garissa. And moreover because fewer people are using wood and charcoal for energy, there is less deforestation and it promotes the sustainable use of land in an area that is vulnerable to desertification.

3. **Encouragement of the Use of Renewable Energy**

It is the first large-scale solar power facility in Kenya and establishes a standard for future solar investments and bolsters Kenya's standing as a renewable energy pioneer in the region.

Moreover, the potential environmental challenges involve the huge solar farms take up a lot of space and may have an impact on wildlife in the area. Also, the future e-waste management issues could arise from the disposal of outdated panels.

**SOCIAL CONTRIBUTIONS:**

Hundreds of thousands of people will benefit from the 50 MW addition to Kenya's national grid which also create the decreases dependency on diesel generators, resulting in more economical and sustainable electricity also this helps to electrify rural areas, enhancing living conditions in Garissa and the surrounding areas.

Futhermore, this as generated more than 1,000 jobs during construction and a number of long-term positions for operations and facilitated the development of a local workforce focused on renewable energy by offering technical training in solar energy. Increases economic stability and corporate productivity by lowering power outages also the social impact of this project as promote the investment in Garissa, a previously underdeveloped area in terms of infrastructure and also ensures a steady supply of electricity to support vital services including hospitals, schools, and businesses. The case of reduceing the amount of kerosene and biomass used for lighting, therefore lowering interior air pollution which results to decrease in the incidence of respiratory conditions connected to emissions from fossil fuels.

## 4.2. DATA ANALYSIS ON CHINA ADVANTAGES TOWARDS SUB-SAHARA AFRICA (THE BUI DAM HYDRO-POWER PROJECT FROM ONE OF THE CASE STUDIES).

Base on our research paper, China as created a lot of advantages to the sub-Sahara Africa in the creation of electricity to the precised countries listed in the paper. Furthermore, China as been able to finance this projects, especially the hydro-power project. The effects of China-financed infrastructure are not well studied empirically, despite a rise in studies on Chinese models of financing infrastructure in these areas. We estimate the effects of the China-financed Bui Dam in Ghana using primary data from the Demographic and Health Survey (DHS) Program Database and the Johns Hopkins SAIS CARI China-Africa Loan Database.

In 2007, it was stated that the hydro-power project began and which was completed in 2013 with estimated financed sum of 306 million dollars on the Bui Hydropower Project (CL part) and 292 million dollars as the Bui Hydro-power Power(CommL part) and this project was able to provide a 400MW power capacity. To determine the change in the likelihood of having access to electricity and owning multiple electric appliances among the more than 29,000 local households that receive electricity transmitted from the Bui Dam, we employ two **difference-in-differences models.**

The probability that residents in the treatment region would have access to electricity rose by almost 4% following the completion of the Bui Dam, according to our data. Our models also imply that the Bui Dam's enhancement of electrification may be primarily seen in urban and affluent households, since urban households had an average 14.5% rise in their likelihood of having access to power. The amount of investment, the total amount of electricity installed, and the hydropower project's lender and contractor were all derived from CARI's statistics. Since 1984, the DHS program has conducted representative household-based surveys in over 70 countries, primarily in developing nations, from which we obtained demographic and health data. There are eight DHS indicators that focus on women, children, household characteristics, health, etc. In order to provide household data at the subnational level, the DHS database combines GPS household data with the outcomes of DHS surveys. To ascertain the socioeconomic impacts of these projects on nearby families, we can thus merge CARI's data on China-financed dams with the regionally relevant DHS data. Futhermore, we chose our treatment group to consist of homes in the four regions that receive energy transmitted from the Bui Dam—Brong-Ahafo, Northern, Upper West, and Upper East—in order to compare regions with and without electricity transmitted from the Bui Dam. Situated on the border between the Northern and Brong Ahafo regions, the Bui Dam was finished in 2013. The 400 MW plant is expected to enhance the quality of electricity service in the Brong-Ahafo, Northern, Upper East, and Upper West regions, particularly the Brong-Ahafo and Northern regions that are adjacent to the dam. Additionally, 240 km of power transmission lines have been constructed to transfer power generated from the Bui Dam to four major nearby towns: Sawla, Techiman, Kintampo, and Sunyani. Prior to the Bui Dam's construction being finished in 2013, these four regions had comparatively less access to energy than the majority of the other six regions, as seen in Figure 2. Specifically, fewer than 70.5% of households in the Northern, Upper East, and Upper West regions have access to electricity. The Bui Dam will provide these areas with the electricity they require. As per a report by the International Water Power & Dam Construction, the dam will enhance Ghana's ability to generate energy by almost 20%.

Ghana had only two major hydroelectric projects prior to the completion of the Bui Dam: the Akosombo Dam and the Kpong Dam. These two dams had been producing energy since 1965 and 1982, respectively, and primarily supplied electricity to the Southern and Eastern regions.

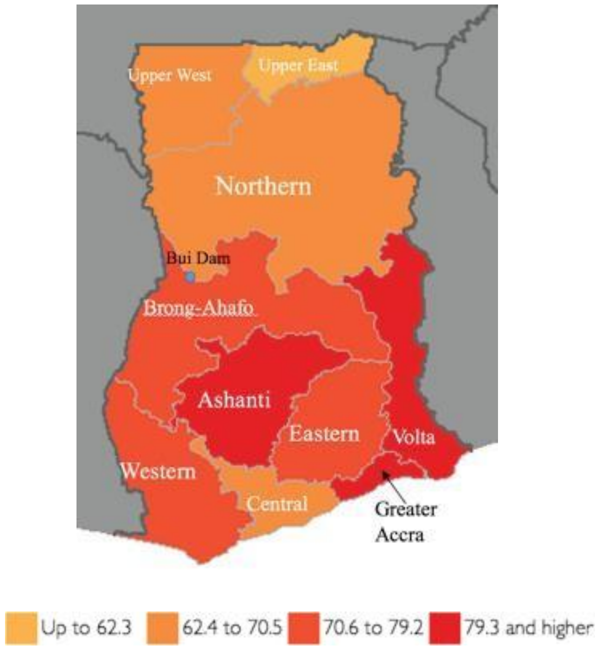



***Figure 2: Percentage of Households with Electricity in Ghana 2008***

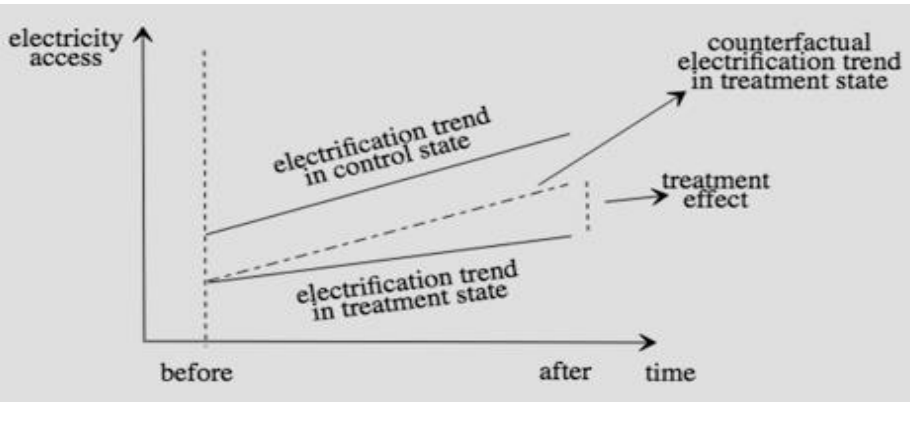
The Bui Dam's effects during the past five years can be mostly linked to the improvement in household access to electricity in the areas, as no other significant dam has been built recently. We selected regions within Ghana to serve as the control group in order to make it as similar to the treatment group as possible. There are only 10 administrative regions in Ghana, and four of them may benefit from better access to power thanks to the Bui Dam. We use the remaining six regions as the control group in order to compare more observations and produce meaningful results. The households in the control group are from the following six regions: Greater Accra, Ashanti, Central, Eastern, Volta, and Western. Even though it might be impossible to say that the control regions receive no electricity transmitted from the Bui Dam, the treatment regions' notable increase in electricity access following the completion of the Bui Dam will not be impacted by the possibly overlooked spillover of the Bui Dam electricity transmission. The impact of the dam on national electricity access may perhaps be underestimated due to the possibly overlooked spillover consequences. The DHS program, our primary data source for socio-economic evaluation indicators, does not have data for every year, and their most recent surveys on Ghana were carried out in 2008, 2014, and 2016. For the purpose of comparing the time periods before and after dam construction, we used DHS 2008 indicators prior to the completion of the Bui Dam, and DHS 2014 and MIS 2016 for indicators following its completion. We selected these years because there are 29,454 observations in total in this repeated cross-sectional database.

Consequently, we compare the differences between household characteristics before and after 2013, as well as between households residing inside and outside the regions where the Bui Dam's electricity is transmitted, in order to assess the vertical and horizontal socioeconomic impacts of the Bui Dam.

## 4.3. EMPIRICAL FRAMEWORK

Selection bias is one of the reasons why it is so hard to measure. The socio-economic impacts of electrification. According to Angrist and Steffen, one of the main challenges in assessing development projects is to make sure you are comparing apples to apples by ruling out pre-existing differences between the treatment and control groups. As Figure 3 illustrates, a more accurate treatment effect can only be predicted after accounting for the selection bias between the treatment and control groups. In our example, we are unable to directly compare household access to electricity in regions where the Bui Dam transmits power with the other regions without disregarding pre-existing differences between the two groups.

**Figure 3: Selection Bias**




***Source: Authors' Research, Adapted from Angrist and Steffen (2008) Figure 5.2.1***

Nevertheless, the issue of selection bias has been discussed in some literature, which has attempted to resolve it using econometric or statistical techniques. For example, Angrist and Steffen contend that the most effective method of removing selection bias is through a randomized controlled experiment (RCT). A randomized phasing-in of electrification is challenging to implement when assessing the socio-economic impacts of hydropower projects, according to Lenz et al. However, they propose that a non-randomized difference-in-differences (DiD) approach can account for unobserved differences between the households of electrified and non-electrified communities under the Rwanda Electricity Access Role-Out Program.

Two difference-in-differences (DiD) models are put out by us to assess the socioeconomic effects of the Bui Dam. The first DiD estimate displays the overall changes in effects across various locations over time, but the triple DiD model includes an urban dummy variable to display the differences in Bui Dam influences between urban and rural areas.

## DIFFERENCE-IN-DIFFERENCES (DID) MODEL

$$yijt = \partial + \beta 1\ Damij + \beta 2\ Postt + \beta 3\ Damij * Postt + \beta 4\ Regionj + \varepsilon ijt \qquad (1)$$

The following are represented by the notations in equation (1):

$\partial$: a constant;

$i$: one household;

$j$: 10 administrative regions in Ghana;

$t$: year (2008, 2014, and 2016) of the socio-economic outcome survey;

$yijt$: outcome variable (such as electricity access, wealth quantile, and ownership of electric appliances) for household $i$ in $j$ region in the year $t$;

$Damij$: a binary variable taking a value of one when household $i$ is located in one of the four regions to which the Bui Dam transmitted electricity: Brong-Ahafo, Northern, Upper East, and Upper West. It takes a value of zero when the household $i$ in region $j$ belongs to the other six areas to which the Bui Dam's electricity is not transmitted;

$Postt$ : a binary variable that denotes whether the year is before or after the Bui Dam's completion;

$Damij * Postt$ : the interaction term that shows the average treatment effects;

$Regionj$ : the 10 administrative regions in Ghana;

$\varepsilon ijt$: an error term.

The first model uses "β3" as the DiD estimator to measure how households in the treatment regions changed their chances of having access to electricity before and after the construction of the Bui Dam.

## DIFFERENCE-IN-DIFFERENCE-IN-DIFFERENCES (TRIPLE DID) MODEL

While MODEL 1 is able to estimate the combined rural-urban treatment effect of the Bui Dam on treatment group families, it is unable to demonstrate the treatment effects that differ across urban and rural households. Due to Ghana's historically lower rural electrification rate than its urban areas, we wish to look more closely at whether the effects of the Bui Dam differ for households in rural and urban areas. In 2016, urban families' rate of access to electricity was 23.2 percentage points greater than that of their rural counterparts, despite the gap closing.

By incorporating an urban dummy variable into Model 1, we created a triple DiD model to demonstrate whether the Bui Dam increased urban families' access to power more than rural households:

$$y_{ijt} = \partial + \beta 1\, Dam_{ij} + \beta 2\, Post_t + \beta 3\, Urban_i + \beta 4\, Dam_{ij} * Post_t + \beta 5\, Dam_{ij} * Post_t * Urban_i + \beta 6\, Dam_{ij} * Urban_i + \beta 7\, Post_t * Urban_i + \beta 8\, Region_j + \varepsilon_{ijt} \quad (2)$$

Other than the following, all of the notations in function (2) are identical to those in function (1):

$Urban_i$ : equals one if household $i$ is urban and zero if it is rural;

$Dam_{ij} * Post_t * Urban_i$ : an interaction term that shows the average treatment effects on urban households;

$Dam_{ij} * Urban_i$ : covariate of treatment and urban variable;

$Post_t * Urban_i$ : covariate of time and urban variable.

The second model uses $\beta_5$, a triple DiD estimator, to show how urban residents in the treatment regions changed their chances of having access to power before and after the Bui Dam.

Bootstrapping is an econometric technique that we utilized because our cluster sample size of 10 areas is quite tiny and we need a higher cluster sample size to guarantee the robustness of standard error. The regression model was run 400 times,

| | Access to Electricity | Access to Electricity | Cooking fuel Electricity | Cooking fuel Electricity |
|---|---|---|---|---|

and the only standard errors we saw were a few minor ones.

**<u>Table 7: Access to Electricity and Cooking  Fuel Using Electricity</u>**

***NOTE: Adjusted Standard errors in parantheses: *p<0.05, **p<0.01, ***P<0.001***

| | Model 1 | Model 2 | Model 1 | Model 2 |
|---|---|---|---|---|
| 1. dam#1.post | 0.0416*** (0.0121) | -0.0672*** (0.0156) | -0.00384* (0.00168) | -0.00289 (0.00168) |
| 1. post#1.urban 1. dam | | 0.145*** (0.0227) | | 0.00282 (0.00320) |
| 1. dam | -0.261*** (0.0150) | *** -0.205* (0.0152) | 0.00160 (0.00172) | 0.00377* (0.00177) |
| 1. post | 0.164*** (0.00678) | 0.256*** (0.0110) | 0.00550** (0.00116) | 0.00139 (0.000782) |
| 2. region. | 0.0212 (0.0117) | 0.0155 (0.0110) | 0.000136 (0.00168) | -0.0000753 (0.00168) |
| 3. region | 0.199*** (0.00991) | 0.0595*** (0.00960) | 0.0143*** (0.00246) | 0.0112*** (0.00252) |
| 4. region | -0.0778*** (0.0120) | -0.0561* (0.0112) | -0.00327** (0.00126) | -0.00280* (0.00125) |
| 5. region | -0.0715*** (0.0116) | -0.0732*** (0.0106) | 0.00308 (0.00188) | 0.00294 (0.00187) |
| 6. region | 0.0995* (0.0109) | 0.0499*** (0.0103) | 0.00217 (0.00168) | 0.000822 (0.00167) |
| 7. region | 0.117*** (0.0135) | 0.0161 (0.0121) | 0.000447 (0.00163) | 0.000122 (0.00158) |
| 8. region | -0.0365** (0.0139) | -0.0832* (0.0121) | 0.00451 (0.00207) | 0.00430* (0.00205) |
| 9. region | -0.137*** (0.0147) | -0.149*** (0.0128) | -0.00192 (0.00142) | -0.00222 (0.00141) |
| 1. urban | | 0.411*** (0.0115) | | 0.00300* (0.00138) |
| 1. dam#1.urban | | 0.133** ** (0.0192) | | -0.00774*** (0.00191) |
| 1. post#1.urban | | -0.214*** (0.0131) | | 0.00672** (0.00215) |
| _cons | 0.613*** (0.00935) | 0.442*** (0.0108) | 0.000563 (0.00128) | -0.0000134 (0.00119) |
| N<br>r2<br>F | 29,454<br>0.138<br>507.7 | 29,454<br>0.268<br>847.4 | 29,454<br>0.00487<br>9.824 | 29,454<br>0.00661<br>11.72 |
| | | | | |

## 4.4. EMPIRICAL RESULTS

### ACCESS TO ELECTRICITY & COOKING FUEL WITH ELECTRICITY

We can observe from both models that, as Table 7 demonstrates, the likelihood that every household will have access to electricity has significantly increased. According to Model 1, after the Bui Dam was built, Ghanaian households in the four regions had 4.16 percent more access to power. Only urban families, whose access to power increased by 14.7% following the treatment, are included in the broader increase in electricity availability. This suggests that urban residents may have received a major portion of the electricity produced by the Bui Dam.

The so-called "last-mile problem" and the absence of rural electrification infrastructure may be the cause of the gap between rural and urban areas in the improvement of access to electricity. Sackey claims that the power plants, district capitals, and neighboring towns—all of which are categorized as metropolitan locations in the DHS database—are connected by an integrated network of lines, distribution centers, control plants, and substations that make up Ghana's electrical transmission system. There are a number of reasons why there is a disconnect between the transmission infrastructure of urban and rural areas, one of which is the high cost of constructing long-distance transmission lines to service small communities. This problem is made worse for rural communities that cannot afford high enough rates to maintain transmission infrastructure. Ghana's Universal National Tariff (UNT) structure also requires rural families to pay a significant amount of their income for expensive electricity in order to cover the expense of installing rural extension transmission lines if they wish to have access to electricity. Due to the high expense of connecting individual homes to the grid, known as the "last-mile problem," small-scale or rural communities may decide to switch from costly grid-based electricity to more reasonably priced electricity produced directly by solar panels, batteries, and similar devices. Additionally, field research conducted in the Bui resettlement community demonstrates that rising electricity costs reduce people' appetite for electricity.

The Bui Dam may have indirectly increased the amount of electricity sent to rural areas even if none of its own electricity was sent there, as it is difficult to measure the spillover effect of grid electricity due to the existence of informal connectivity of electricity through neighborhood sharing. Nevertheless, it is difficult to argue that the Bui Dam has not improved rural electrification at all. Even if all of the dam's electricity were transmitted to urban areas, this might have allowed electricity from other sources that would have gone to urban areas to then become available for rural areas. A living commune consisting of multiple families that permits them to share utilities like a single electric metering system is known as a "compound house," which is the primary feature of a residential community, according to earlier research on Ghana's power transmission system. The same is true for rural households who are not connected to the grid; they can nevertheless obtain electricity by connecting illegally to an urban region.

We examined the effects on the rate of electricity use for cooking in addition to the availability of electricity. Model 2 did not yield any significant coefficients. According to Model 1, the number of homes utilizing electricity for cooking fell by 0.3 percent following the completion of the Bui Dam. But since the correlation coefficient is so low—0.3 percent does not indicate a significant impact—and because cooking with electricity necessitates the use of some electric tools, like electric cooktops, which are comparatively more costly and might be out of reach for Ghanaians, particularly those from the less developed Northern Ghana, we are not confident enough to assert that this result has a strong correlation with the Bui Dam. The decline in the proportion of households using electricity for cooking may be due to the costlier electric cooking equipment for households in the dam areas compared to those in the control regions, rather than a decline in accessibility or willingness to use electricity for cooking. Prior studies have similarly shown that electrification did not significantly increase the amount of energy used in rural China, India, or Thailand for heating or cooking.

## OWNERSHIP OF ELECTRIC APPLIANCES

The two did models enabled us to examine whether, in comparison to households in the control regions, the likelihood of owning different electric appliances increased more quickly for households in the four treatment regions (the Brong-Ahafo, Northern, Upper East, and Upper West regions). Since people might only buy electric devices like computers, refrigerators, TVs, washing machines, telephones, cell phones, and radios once every few years, our DiD estimators calculate the rate of household ownership of these appliances at the aggregate level rather than their purchasing patterns. Tables 8 and 9 demonstrate a very notable increase in the likelihood that households will own electric appliances, with the exception of washing machines. The overall rate of household ownership of TVs, refrigerators, and PCs fell by 2.37, 3.31, and 2.85 percent, respectively, according to the regression results in Table 9.

One possible explanation for the Model 1 result that people purchase fewer computers, refrigerators, and televisions after the dam is completed is that these items are probably luxury goods in Ghana, so the population with the highest incomes will have the greatest access to them. If the ownership of these items by wealthier households increases more slowly in the dam regions than in the control regions, this would give the impression that the dam decreased the use of these items.

A regression of Model 1 on the richest, richer, middle, poorer, and poorest households, respectively, based on the DHS wealth index—which is determined by households' ownership of specific assets, types of water access and sanitation facilities, and materials used for housing construction—is conducted to further test how wealth distribution may have impacted the negative coefficients in Model 1 results. Although the results for the richest and richest households are not statistically significant, the regression results in Tables 10, 11, and 12 demonstrate that: (1) the likelihood of refrigerator ownership fell by 8.84 percent among richer households compared to their counterparts in the control group; and (2) the ownership of computers increased by 6.92, 3.27, and 0.51 percent among middle-income, poorer, and poorest households, respectively, following the completion of the Bui Dam. However, once the Bui Dam was completed, the ownership of refrigerators climbed by 5.63 and 1.25 percent for the poorest and poorest households, respectively; (3) the ownership of TVs increased by 5.54 percent for the poorest households and declined by 12.4 percent for the richer households.

**Table 8: Electric Appliances Ownership**

| | Computer | Computer | Refrigerator | Refrigerator | TV | TV | Washing Machine | Washing Machine | Telephone | Telephone |
|---|---|---|---|---|---|---|---|---|---|---|

| | Model 1 | MOdel 2 | MOdel 1 | Model 2 | Model 1 | MOdel 2 | Model 1 | Model 2 | Model 1 | Model 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. dam#1. post | -0.0237*** (0.00648) | -0.0312*** (0.00670) | - 0.0331** (0.0102) | -0.0834* (0.0102) | -0.0285* (0.0123) | 0.0105 (0.00587) | 0.00310 (0.00342) | 0.00976 (0.00508) | 0.0271** * (0.00473) | 0.0105 (0.00587) |
| 1. post 1. urban #1. dam | | 0.0483*** (0.0144) | | 0.123*** (0.0233) | | 0.0262* (0.0104) | | -0.00506 (0.00720) | | 0.0262* (0.0104) |
| 1. dam | -0.0288*** (0.00773) | -0.00814 (0.00759) | - 0.133*** (0.0128) | -0.0591 (0.0113) | -0.247*** (0.0148) | -0.0109* (0.00550) | -0.0121** (0.00309) | -0.0127** (0.00462) | - 0.0257** * (0.00435) | -0.0109* (0.00550) |
| 1. post | 0.0777*** (0.00594) | 0.0512⋆ *** (0.00664) | 0.0823** (0.00853 ) | (0.00968) 0.0930*** | 0.186*** (0.00890) | (0.00572) -0.0187** | 0.00414 (0.00353) | (0.00525) -0.00877 | (0.00435) - 0.0396** * | -0.0187* (0.00572) |
| 2014 year | -0.00469 (0.00517) | -0.00772 (0.00510) | -0.00110 (0.00693 ) | -0.00802 (0.00667) | -0.0129 (0.00755) | 0.00459* * (0.00151) | -0.000203 (0.00203) | -0.000581 (0.00203) | 0.00478* * (0.00152) | 0.00459* * (0.00151) |
| 2. region | -0.0153* (0.00771) | -0.0179* (0.00760) | - 0.000539 (0.0122) | -0.00679 (0.0118) | -0.0547*** (0.0131) | -0.00388 (0.00304) | -0.00558* (0.00279) | -0.00604* (0.00279) | -0.00363 (0.00307) | -0.00388 (0.00304) |
| 3. region | 0.118*** (0.00872) | 0.0748*** (0.00919) | (0.0120) 0.327*** | 0.202** *** (0.0123) | 0.281** (0.0114) | (0.00741) 0.0562** * | (0.00419) 0.0357*** | (0.00457) 0.0303** * | (0.00708) 0.0670** * | 0.0562** * (0.00741) |
| 4. region | -0.0520*** (0.00766) | -0.0454*** (0.00752) | - 0.0875** * (0.0112) | -0.0683*** (0.0109) | -0.150*** (0.0127) | (0.00417) -0.00607 | -0.00921* (0.00404) | -0.00840* (0.00398) | (0.00424) -0.00775 | -0.00607 (0.00417) |
| 5. region | -0.0279*** (0.00722) | -0.0294*** (0.00706) | - 0.0384** * (0.0108) | -0.0412*** (0.0103) | -0.0875*** (0.0127) | -0.00583 (0.00396) | -0.00159 (0.00397) | -0.00193 (0.00396) | -0.00593 (0.00398) | -0.00583 (0.00396) |
| 6. region | 0.0232** (0.00839) | 0.00538 (0.00843) | 0.148*** (0.0115) | 0.0999*** (0.0111) | 0.0967*** (0.0122) | 0.00741 (0.00580) | 0.00881 (0.00524) | (0.00561) 0.00619 | 0.0107 (0.00545) | 0.00741 (0.00580) |
| 7. region | 0.0109 (0.00690) | -0.00935 (0.00688) | 0.0949** * (0.0105) | 0.0413*** (0.0103) | 0.140*** (0.0130) | -0.00233 (0.00237) | 0.00572* (0.00225) | (0.00221) 0.00363 | - 0.000073 4 (0.00236) | -0.00233 (0.00237) |
| 8. region | -0.00824 (0.00662) | -0.0182** (0.00648) | 0.0160 (0.00994 ) | (0.00945) - 0.00960 | 0.0387** (0.0139) | -0.00183 (0.00238) | -0.00243 (0.00155) | -0.00351* (0.00162) | - 0.000861 (0.00239) | -0.00183 (0.00238) |
| 9. region | -0.0101 (0.00688) | -0.0153* (0.00668) | 0.299** (0.0105) | 0.0205* (0.00964) | (0.0138) - 0.00953 | 0.00534 (0.00291) | (0.00183) - 0.000829 | -0.00160 (0.00185) | 0.00522 (0.00293) | 0.00534 (0.00291) |
| 1. urban | | 0.0710*** (0.00748) | | 0.293*** (0.0112) | | 0.0454** * (0.00869) | | -0.000734 (0.00661) | | 0.0454 (0.00869 |
| 1. dam#1. urban | | -0.0292** (0.0106) | | -0.0760*** (0.0196) | | -0.0235* (0.0102) | | -0.000768 (0.00664) | | -0.0235 (0.0102) |
| 1. post #1. urban | | 0.0398** (0.00942) | | -0.0500*** (0.0136) | | - 0.0422** * (0.00870) | | 0.0229** * (0.00657) | | - 0.0422** * (0.00870) |
| _cons | 0.0585** (0.00587) | 0.0353*** (0.00604) | 0.211*** (0.00899 ) | 0.0974*** (0.00891) | 0.438*** (0.00994) | 0.0183** * (0.00504) | 0.0188* (0.00284) | 0.0140** * (0.00445) | 0.0387** * (0.00364) | 0.0183** *(0.0050 4) |
| N R 2 F | 29,454 0.0384 87.44 | 29,454 0.0608 107.5 | 29,454 0.104 255.9 | 29,454 0.173 437.0 | 29,452 0.123 414.6 | 29,451 0.0204 18.99 | 29,454 0.00734 26.77 | 29,454 0.00927 24.28 | 29,451 0.0175 16.36 | 29,451 0.0204 18.99 |

***NOTE: Adjusted Standard errors in parantheses: *p<0.05, **p<0.01, ***P<0.001***

## Table 9: Electric Appliances Ownership(Radio and Mobile Phone)

| | Radio | Radio | Mobile | Mobile telephone |
|---|---|---|---|---|

| | | | Telephone | |
|---|---|---|---|---|
| | Mobile 1 | Mobile 2 | Mobile 1 | Mobile 2 |
| 1. dam 1.post | 0.0111 (0.0122) | 0.0220 (0.0161) | 0.127*** (0.0115) | 0.0485*** (0.0147) |
| 1. post#1.urban" 1. dam | | -0.0502* (0.0253) | | 0.0501* (0.0237) |
| 1. dam | -0.140*** (0.0151) | -0.136*** (0.0168) | -0.254*** (0.0146) | -0.191*** (0.0152) |
| 1. post | -0.0880*** (0.00729) | -0.0797*** (0.0106) | 0.272*** (0.00639) | 0.402*** (0.00966) |
| 2. region | -0.0684*** (0.0126) | -0.0698* (0.0125) | -0.0391*** (0.0109) | (0.0105) - 0.0427*** |
| 3. region | 0.0598** (0.0116) | 0.0291* (0.0120) | 0.203*** (0.00916) | 0.0958** (0.00907) |
| 4. region | -0.0455*** (0.0122) | -0.0408*** (0.0122) | -0.0236* (0.0109) | -0.00695 (0.0105) |
| 5. region | -0.0145 (0.0119) | -0.0151 (0.0119) | -0.0331** (0.0110) | -0.0334** (0.0105) |
| 6. region | 0.0532*** (0.0118) | (0.0118) 0.0418*** | 0.0699*** (0.0100) | 0.0345*** (0.00956) |
| 7. region | 0.116*** (0.0134) | 0.104*** (0.0135) | 0.142*** (0.0126) | (0.0120) 0.0889** |
| 8. region | -0.0267 (0.0143) | -0.0320* (0.0142) | 0.0622*** (0.0134) | 0.0387** (0.0127) |
| 9. region | 0.0315* (0.0146) | 0.0318* (0.0145) | 0.0696*** (0.0134) | 0.0683*** (0.0127) |
| 1. urban | | 0.0787** (0.0121) | | 0.0374*** (0.0110) |
| 1. dam#1.urban | | 0.0321 (0.0201) | | 0.0370 (0.0212) |
| 1. post#1.urban | | -0.0249 (0.0148) | | -0.275*** (0.0214) |
| _cons | 0.766*** (0.00931) | 0.735*** (0.0108) | 0.567** (0.00896) *** | 0.405*** (0.0101) |
| N<br>r2<br>F | 29,454<br>0.0282<br>68.55 | 29,454<br>0.0322<br>57.43 | 29,454<br>0.160<br>513.0 | 29,454<br>0.232<br>633.2 |

***NOTE: Adjusted Standard errors in parantheses: *p<0.05, **p<0.01, ***P<0.001***

This breakdown of Model 1's results for households in each of the five wealth quintiles may suggest that the fact that wealthy people are much more likely to be able to purchase computers, TVs, and refrigerators may be the reason for the overall negative DiD coefficient of all households' ownership of these devices. In the dam areas, the comparatively slower rise in ownership among the wealthier households balances the comparatively quicker rise in ownership among the impoverished households. High-income households may have had a very minor impact from the dam because they already owned many of these appliances, which may help to explain why their influence was so minimal.

**Table 10: Computer Ownership by Wealth Quantile**

| | Richest | Richer | Middle | Poorer | Poorest |
|---|---|---|---|---|---|
| 1. dam | 0.0799 (0.0589) | 0.150*** (0.0303) | 0.0119 (0.0155) | -0.00889 (0.00720) | -0.00247* (0.00111) |
| 1. post | 0.184*** (0.0137) | 0.0934*** (0.00710) | 0.0361*** (0.00583) | -0.00534 (0.00908) | 0.000711 (0.000719) |
| 1. dam#1.post | 0.0582 (0.0424) | 0.0209 (0.0200) | 0.0692*** (0.0117) | 0.0327** (0.0104) | 0.00512*** (0.00155) |
| 2. region | 0.0193 (0.0308) | 0.00296 (0.0156) | -0.00837 (0.00883) | 0.00749 (0.00413) | -0.000226 (0.000231) |
| 3. region | 0.00397 (0.0227) | -0.0334** (0.0129) | -0.0188* (0.00948) | 0.0132 (0.0108) | 0.0255 (0.0252) |
| 4. region | -0.0487 (0.0363) | 0.00263 (0.0170) | -0.0172* (0.00851) | 0.0129 (0.0122) | -0.0000712 (0.0000773) |
| 5. region | -0.00126 (0.0308) | 0.00186 (0.0155) | -0.00995 (0.00876) | 0.00243 (0.00306) | -0.0000793 (0.0000852) |
| 6. region | -0.0774** (0.0245) | 0.00194 (0.0137) | 0.0102 (0.0139) | 0.0310 (0.0187) | -0.0000141 (0.0000358) |
| 7. region | -0.0793 (0.0572) | -0.152*** (0.0307) | -0.0414* (0.0183) | -0.00363 (0.00673) | 0.00104 (0.00183) |
| 8. region | -0.0263 (0.0637) | -0.118** (0.0362) | -0.0246 (0.0206) | 0.0184 (0.0102) | 0.00329 (0.00183) |
| 9. region | 0.0640 (0.0678) | -0.0978* (0.0398) | -0.0140 (0.0260) | 0.0122 (0.0112) | 0.00546* (0.00216) |
| _cons | 0.270*** (0.0216) | 0.0311** (0.0110) | 0.0139* (0.00695) | 0.00556 (0.00518) | -0.000357 (0.000362) |
| N | 5,317 | 5,822 | 5,991 | 5,857 | 6,467 |
| r2 | 0.0484 | 0.0458 | 0.0252 | 0.00324 | 0.00525 |
| F | 24.97 | 26.96 | 20.59 | 4.008 | 1.740 |

***NOTE: Adjusted Standard errors in parantheses: *p<0.05, **p<0.01, ***P<0.001***

We can observe how the average ownership of electric appliances in the dam regions may have been impacted by wealth distribution in Model 1, and we can also detect an urban-rural divide in Model 2. Table 8 demonstrates that the percentage of urban households who own computers, refrigerators, and televisions has increased by 4.83, 12.3, and 20.8 percent, respectively. This would suggest that following the building of the Bui Dam, urban households owned and used these equipment more frequently.

On the other hand, Table 9 demonstrates that the increase in telephone and mobile phone ownership among urban households was less than that of rural households. The Model 2 and Model 1 households' respective increases in telephone and mobile phone ownership were 2.62 and 5.01 percent, while the Model 1 households' increases were 2.71 and 12.7%. This suggests that the number of rural households owning mobile phones and landlines increased faster than that of urban households. Additionally, while radio ownership is not significant in Model 1, it is in Model 2, which indicates a 5.02 percent decline in the chance of radio ownership in urban households.

**Table 11: Refrigerator Ownership by Wealth**

| | Richest | Richer | Middle | Poorer | Poorest |
|---|---|---|---|---|---|
| 1. dam | 0.0364 (0.0526) | 0.169* (0.0666) | 0.0144 (0.0243) | -0.0101 (0.0104) | -0.00964* (0.00397) |
| 1. post | 0.0218 (0.0119) | 0.157*** (0.0161) | 0.143*** (0.00876) | 0.0217* (0.00980) | 0.00153 (0.00253) |
| 1. dam#1.post | 0.0211 (0.0329) | -0.0884* (0.0390) | -0.0120 (0.0195) | 0.0563*** (0.0132) | 0.0125*** (0.00336) |
| 2. region | 0.0487 (0.0273) | 0.0673* (0.0325) | 0.00354 (0.0167) | 0.0122 (0.00715) | -0.00460 (0.00460) |
| 3. region | 0.133*** (0.0206) | -0.0169 (0.0246) | -0.0796*** (0.0168) | 0.0149 (0.0153) | 0.0212 (0.0256) |
| 4. region | 0.137*** (0.0286) | -0.0118 (0.0286) | -0.0241 (0.0167) | 0.0161 (0.0134) | 0.0000332 (0.00525) |
| 5. region | 0.0797** (0.0266) | 0.00500 (0.0263) | 0.00783 (0.0170) | 0.0147* (0.00686) | -0.00429 (0.00427) |
| 6. region | 0.142*** (0.0210) | 0.0746** (0.0236) | 0.0146 (0.0171) | 0.0495* (0.0199) | -0.00415 (0.00414) |
| 7. region | 0.0654 (0.0464) | -0.0343 (0.0556) | 0.00263 (0.0239) | -0.00912 (0.0111) | 0.00135 (0.00271) |
| 8. region | 0.0780 (0.0507) | -0.00880 (0.0614) | 0.0308 (0.0282) | 0.0423** (0.0160) | 0.00252 (0.00227) |
| 9. region | 0.113* (0.0513) | 0.0827 (0.0629) | 0.139*** (0.0391) | 0.0773*** (0.0213) | 0.0196*** (0.00397) |
| _ cons | 0.726*** (0.0200) | 0.267*** (0.0213) | 0.0449*** (0.0125) | 0.0000105 (0.00616) | 0.00335 (0.00358) |
| N<br>r2<br>F | 5,317<br>0.0144<br>6.903 | 5,822<br>0.0266<br>15.89 | 5,991<br>0.0508<br>36.36 | 5,857<br>0.0148<br>12.04 | 6,467<br>0.0137<br>4.730 |

***NOTE: Adjusted Standard errors in parantheses: *p<0.05, **p<0.01, ***P<0.001***

**Table 12: Television Ownership by Wealth**

| | Richest | Richer | Middle | Poorer | Poorest |
|---|---|---|---|---|---|

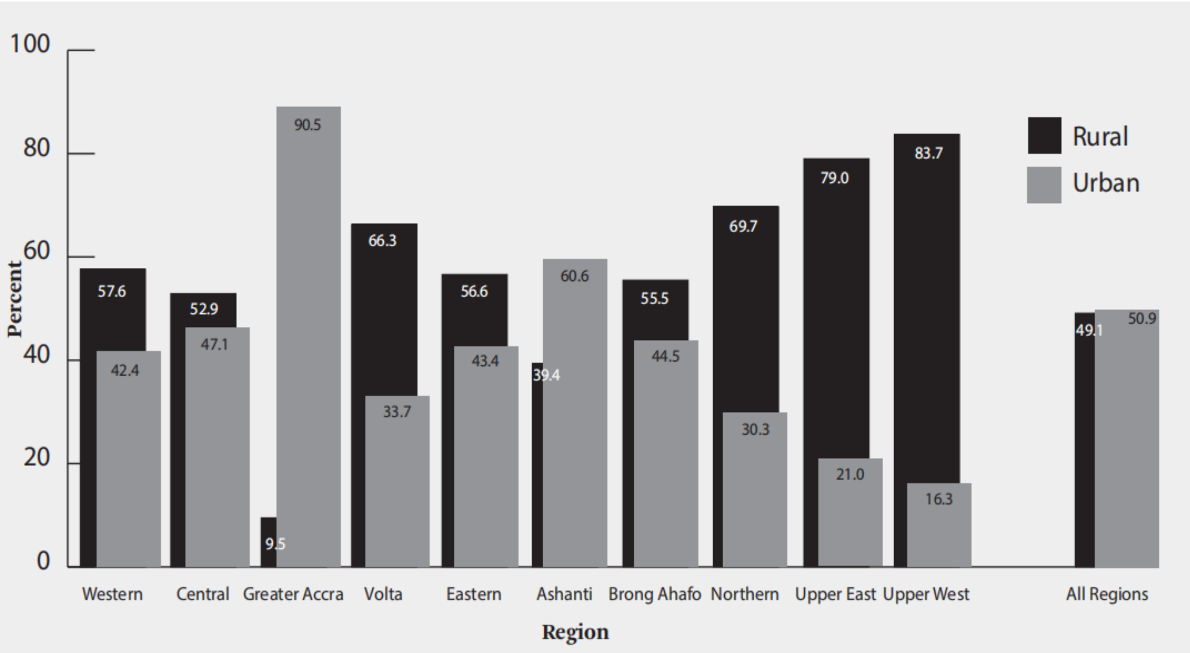
| | | | | | |
|---|---|---|---|---|---|
| 1. dam | 0.0141<br>(0.0121) | 0.110***<br>(0.0294) | 0.0770*<br>(0.0378) | 0.0650*<br>(0.0270) | 0.00577<br>(0.0116) |
| 1. post | -0.00487<br>(0.00524) | 0.180***<br>(0.0127) | 0.371***<br>(0.0154) | 0.208***<br>(0.0124) | (0.00799)<br>0.0471*** |
| 1. dam#1.post | -0.0108<br>(0.00926) | -0.124***<br>(0.0231) | -0.0152<br>(0.0285) | 0.0420<br>(0.0299) | 0.0554***<br>(0.00986) |
| 2. region | -0.00410<br>(0.00911) | -0.0507*<br>(0.0203) | -0.0945***<br>(0.0246) | -0.00565<br>(0.0181) | 0.0221<br>(0.0206) |
| 3. region | 0.00606<br>(0.00718) | -0.0531**<br>(0.0181) | -0.187***<br>(0.0339) | -0.00155<br>(0.0349) | 0.301***<br>(0.0746) |
| 4. region | -0.00909<br>(0.0121) | -0.0378<br>(0.0223) | -0.0796***<br>(0.0234) | 0.0109<br>(0.0181) | 0.00696<br>(0.0121) |
| 5. region | -0.00432<br>(0.00920) | 0.00120<br>(0.0239) | -0.0530*<br>(0.0233) | -0.000630<br>(0.0173) | -0.0000724<br>(0.0119) |
| 6. region | 0.00242<br>(0.00675) | 0.00437<br>(0.0174) | -0.0225<br>(0.0235) | 0.0232<br>(0.0281) | 0.00919<br>(0.0145) |
| 7. region | -0.0109<br>(0.0137) | -0.00214<br>(0.0261) | -0.106**<br>(0.0338) | -0.0774**<br>(0.0247) | -0.0221*<br>(0.0105) |
| 8. region | 0.0101<br>(0.0104) | 0.0394<br>(0.0295) | 0.0939*<br>(0.0385) | 0.131**<br>(0.0436) | 0.0130<br>(0.00973) |
| 9. region | -0.00980<br>(0.0160) | 0.0816**<br>(0.0270) | 0.168***<br>(0.0416) | 0.154**<br>(0.0487) | -0.000379<br>(0.00943) |
| _cons | 0.985***<br>(0.00686) | 0.729***<br>(0.0167) | 0.273***<br>(0.0193) | 0.0364**<br>(0.0122) | -0.00309<br>(0.00976) |
| N<br>r2<br>F | 5,317<br>0.00144<br>6.050 | 5,822<br>0.0526<br>28.07 | 5,991<br>0.145<br>99.28 | 5,856<br>0.0714<br>70.35 | 6,466<br>0.0496<br>33.66 |

***NOTE: Adjusted Standard errors in parantheses: *p<0.05, **p<0.01, ***P<0.001***

In contrast to rural households, which had a greater increase in telephone and mobile phone ownership, urban households showed a faster increase in computer, refrigerator, and television ownership. This could be the result of urban households earning more money, which allows them to purchase appliances that are more costly and energy-intensive. Prior research also demonstrates that middle-class and upper-class urban households tend to acquire more high-wattage appliances, such as air conditioners, freezers, water heaters, and electric cookers, as access to electricity increases. On the other hand, because of their lower operating costs, low-wattage devices like radios, phones, and cell phones might be more accessible and reasonably priced for rural homes. Additionally, it's possible that urban families had these low-wattage appliances in greater numbers prior to the Bui Dam's construction, which is why ownership did not rise significantly.

After the Bui Dam was built, there was a decline in the number of households overall, but an increase in the number of urban homes with computers, refrigerators, and televisions. This tendency is hard to explain. There are two possible reasons why this disparity could exist. In the first place, people may decide to relocate from rural to urban areas in search of better living conditions. Second, people may have migrated to southern Ghana, which has more urban towns, from the sparsely populated northern region. In 2000, 43.8% of the population lived in urban areas; in 2012, that percentage was 50.9%, according to a data released by the Ghana Statistical Service. Ownership of electric equipment naturally declines or increases more slowly in rural areas than in urban ones when a smaller percentage of the population resides there. As seen in Figure 4, the majority of people live in rural areas in the four regions that are connected to the Bui Dam: the Brong-Ahafo, Northern, Upper East, and Upper West regions.

**Figure 4: Population by type of Locality(urban and rural) in Ghana - 2010**




Source: Ghana Stasticial Service, 2012.[53]

# CHAPTER 5

# ECONOMIC CO-ADVANTAGES AND THERE DETERMINANTS

The technical aspects of the three projects vary greatly, but they can be compared and analyzed by using the frameworks described in Chapter 2. An overview of the identification of co-benefits is given at the beginning of this last analytical section, which then moves on to an exploratory consideration of the factors that influence these benefits.

Additionally, Table 13 summarizes important details about the different kinds of co-benefits. Overall, there is evidence that the local economies are receiving bounded co-benefits. Benefits were often "limited." When we say "limited," we imply that the degree of a particular co-benefit found in a project is at the lowest endpoint of one of the three continua listed in this paper's Appendix A2. The term "significant," on the other hand, refers to a project that is near the highest level at the other end of the spectrum. But it's crucial to remember that each of the three benefit categories contains multiple indicators (meaning they are composite indicators) and that there might be variations among them.

While direct employment creation was substantial, it varied depending on the stage of the project. Local employees, who made up 70–90% of all project employers, dominated the building phase of the projects. Nonetheless, the majority of local jobs were limited to semi-skilled or low-skilled tasks, and with rare exceptions, Chinese immigrants performed the majority of highly skilled jobs. The main responsibilities throughout the operating phase, which included fewer but more permanent positions, usually included a gradual transfer of responsibility from Chinese to local employees. Although it was a part of all three projects, the development of backward links from the projects through the supply of local services and manufacturing inputs from local enterprises was restricted.

These connections were typically limited to auxiliary and non-essential parts or services. The majority of core components were either imported from China or, in more developed economies, sourced from specialized suppliers. There are implications for the opportunities for technological learning from the nature of the jobs as well as the (limited) involvement of local suppliers. In general, the operational phase of projects (i.e., the service delivery process) involved operational skills and know-how, as well as minor maintenance capabilities. This was the domain where the most significant capability-acquisition and "knowledge transfers" from China occurred. Significantly less learning took place throughout the economically significant building phase (i.e., the delivery process for new green infrastructure). As we will see below, there was, nevertheless, some intriguing experience-gaining in the non-trivial field of project management and the supervision of technical procedures in networks including technical colleges, engineering consultancies, and local sponsors (energy ministries). All things considered, the utilization of local labor was substantial; however, the utilization of local production and services, as well as the development of local knowledge capacities, were comparatively restricted, while being discernible.

Overall, there is evidence of learning, employment development, and the provision of some local content across all projects. The majority of the considerable benefits did not extend to local content and learning in strategic functions, though, and these co-benefits only appear to be "significant" in relation to particular measures.

## 5.1 THE NATURE OF INBOUND FLOWS OF CAPITAL AND TECHNOLOGY FROM CHINA

Table 14, the nature and flows of capital and technology were important influencing factors when it comes to the realisation of local benefits. Our case studies align with and add to the existing literature on this point (Brautigam and Hwang, 2019; Kaplinsky and Morris, 2009; Lema et al., 2018). The technologies employed in the projects had a significant impact on how co-benefits were created. Their labor intensity, capital needs, and complexity vary widely, all of which have a significant impact on co-benefits. Despite being based on a small number of cases, this finding supports the research on the sectoral features of green technologies, indicating that the benefits of industry localization are very particular to individual technologies (Schmidt and Huenteler, 2016). To put it another way, the specific technical features determine the extent and type of co-benefits. For instance, the Bui case's relatively high degree of local content can be explained by the high transportation costs of cement for construction and the requirement to produce the cement on site. This means that the choice of technology should be a top priority in discussions about greening, and that these discussions should consider important trade-offs between the overall cost (i.e., the levelized cost of electricity) and the expected degree of co-benefits. Furthermore, it is important to recognize that it is not just the choice of core technologies which matters in achieving economic benefits, but also how they are deployed, for example, centralised or decentralised (Hansen et al., 2018).

**Table 13**

**Overview of co-benefits in the three projects.**

| | Adama Wind Project | Bui Dam Hydro Project | Garissa Solar PV Project |
|---|---|---|---|
| Local jobs | During construction the project employed 400 Chinese staff and 1000 local staff. During operation, handover from Hydro China to EEP occurred after five years, thereby transferring operation and maintenance to Ethiopian nationals in EEP. | During construction, 170 Chinese staff and 1600 local staff were employed by the project. Around 50 Ghanaian nationals were involved in operations and routine maintenance undertaken by BPA. Sino Hydro employed in new contract for additional repair construction. | During construction, the project employed 50–75 Chinese staff and nearly 350 local staff, a majority of whom were involved in low-skill activities. During operation, five Kenyan staff and four Chinese nationals are involved. |
| Local content | No local equipment or construction service inputs. Local involvement in the project's completion was confined to transportation services (on-land shipping of the turbines). Turbines and other critical equipment were sourced from China. Important involvement of local universities in capacity of owner's consultant. CSR initiative | Significant provision of locally sourced manufacturing inputs and construction services, in particular provision of concrete for construction. An estimated share of 60% of local content overall, though with critical equipment and components (e.g. turbines) provided from outside. | Local equipment inputs and construction service inputs were limited to auxiliary hardware (e.g. cables and wires). Important involvement of local engineering firm. In addition, functionally unrelated infrastructure was provided, including a school, which included local content. |
| Local learning | Inbound flows of hardware from China along with provision design blueprints and project management frameworks. Interaction between project owner and EPC contractor mediated by university consultants, gaining experience for future construction with foreign EPC contractors. EPC contractor involved in transfer of skills for O&M. Training in China of EEP personnel and university | Critical technology sourced from China, with no or limited local transfer of knowledge and expertise related to core technologies and construction project management. Limited transfer means that maintenance depends on further contracts with Sino-hydro. Deliberate training efforts confined to two-week boot-camps for | Inbound flows of hardware (e.g. panels and inverters) sourced from China along with project design. Involvement of local consulting firm, gaining project-level experience, during feasibility and construction. Deliberate training efforts, including secondments, confined to post construction stages related to |

| | | | |
|---|---|---|---|
| | consultants. | workers working on the construction site. | O&M. |

**Table 14**

**Summary of key determinants**

| | Adama Wind Project | Bui Dam Hydro Project | Garissa Solar PV Project |
|---|---|---|---|
| Nature and flows of capital and technology | The capital-intensive and complex nature of wind turbines reduced the scope for local manufacturing of core technology components. The Hydro-China-CGCOC joint venture, as the project lead, raised funding from China's Exim Bank and specified the use of Chinese wind technology suppliers. | The service-intensive nature of hydro-technology involved local sourcing of roller-compacted concrete, but core technologies (turbines) were only provided by a few global lead firms. Lead agents were the Ghanaian Ministry of Energy (MoE), China Exim Bank and Sinohydro. Loan provided by China Exim Bank on semi-commercial basis. | Intense competition and high entry barriers in solar PV manufacturing implied that localization possibilities were limited to downstream activities, including peripheral procurement, installation services and O&M. EPC mandated to be Chinese in tied financing agreement, with no local co-financing option, limiting local content. CJIC favoured Chinese technology suppliers (Jinko, Byd). |
| Local institutional and economic conditions | The institutional foundation was based on direct negotiations between project developers and EEP. The strategic involvement of local universities in the project was a deliberate intent to facilitate capacity-building. The focus was on accumulating experience in O&M of the wind farms, with little attention to construction. Absence of a local supply base for turbine assembly and wind-farm construction. | One of the first major investments undertaken by Chinese SOEs in Ghana, directly negotiated and envisaged to strengthen Chinese-Ghanaian relations. Local content originally targeted at 90%, whereas Ghanaian negotiators accepted 60% of contracts going to Chinese vendors. Since hydro-power dams are only constructed every few decades, there was a limited domestic supply base in terms of both equipment and labour. | The project initially followed feed-in tariff guidelines that were later renegotiated. Regulation-determined project modality. Limited strategic approach for local employment, capacity development, or supply chain involvement. Local solar capacities concentrated around small-scale solar projects, leaving a limited skill base to carry out large-scale projects. |

| | | | |
|---|---|---|---|
| | | | |
| Characteristics and organisation of the investment project | Turnkey project, with Hydro-China-CGCOC entirely responsible for project design, coordination and management of supply chains. Some upfront specification training requirements in O&M. | Turnkey EPC contract putting Sinohydro in charge of its construction and operation. Complex project with 60 firms involved, of which six were key to its construction. Planned capacity-building mainly related to operational tasks during the construction phase. No capacity for the operation phase of the project. | Turnkey model comprising Chinese companies as lead EPC and main sub-contractors. Tied financing, entirely Chinese EPC, contractors, technology suppliers and financiers offering a full package, and relatively limited avenues for planned capacity-building. |

However, in none of the three cases was the choice of technology for the project rooted in such deliberations or overall national energy plans (with the partial exception of the Bui dam, which depended on a national initiative to a greater degree). On the contrary, the interviews suggest that technology selection was heavily influenced by the Chinese lead agents involved, who had their own technological preferences. In conformity with the previous literature (Ajakaiye and Kaplinsky, 2009; Kaplinsky and Morris, 2009), these investment decisions were typically instigated by Chinese consortia organising projects through investment-centred global value chains (Lema et al., 2018). The analysis suggests that benefits energy plans (with the partial exception of the Bui dam, which depended on a national initiative to a greater degree). On the contrary, the interviews suggest that technology selection was heavily influenced by the Chinese lead agents involved, who had their own technological preferences. In conformity with the previous literature (Ajakaiye and Kaplinsky, 2009; Kaplinsky and Morris, 2009), these investment decisions were typically instigated by Chinese consortia organising projects through investment-centred global value chains (Lema et al., 2018). The analysis suggests that benefits are constrained by a dominant pattern of ‘tied financing’ associated with such chains, and it confirms the role of the nature of finance.

The case of Garissa showed how Jiangxi Province initiated the discussions and favored its own state-enterprise, CJIC, while sourcing finances from China’s Exim Bank. Similarly, the Adama case showed how the major actors in the project, EEP and Hydro-China/CGOCCC, as the EPC contractors negotiated the contract and all contingent decisions. In the Bui case, the Chinese technology suppliers and EPC contractors also followed the Chinese investors in a tied-finance agreement. It was a requirement that investors had to produce the equipment in China in order to be eligible for export support. A non-Chinese contractor (Alstom) also received economic benefits because the equipment used in the project had been produced in China. Moreover, the contractual arrangements for this project, using an EPC contract, could have been more advantageous to the Ghanaian stakeholders, with the MoE and BPA likely to benefit much more from a build-operate transfer (BOT) contract, which would have legally obliged Sinohydro to build the capacities needed for BPA to maintain the Bui Dam. On the other hand, an EPC contract was much more in the interests of Sinohydro, since it might have created additional contracts, for example, for project maintenance, once the first contract had been completed.

## 5.2 THE LOCAL INSTITUTIONAL AND ECONOMIC CONDITIONS

The analysis also indicates that the nature of the project and its co-benefits are greatly influenced by local variables, including local deployment patterns, industrial policies, the domestic supply base, and local capabilities. Building on the arguments in the previous subsection, it is important to remember that, with regard to the host economy deployment policy model for renewable energy, the projects under analysis were negotiated in the midst of weak institutional regimes, or even "institutional voids" (Silvestre, 2015). This meant that even in cases where a feed-in tariff policy was in existence but was eventually evaded (as in the Garissa case) or when there were early intentions for local content but ultimately failed to be reached (as in the Bui case), projects were handled "ad hoc."

The policy position is a crucial factor that can distinguish between "induced co-benefits" and "naturally occurring co-benefits." The majority of co-benefits that have been documented fall into the former category (for example, procuring local cement in the hydro instance), although some case material also suggests that the latter is occurring, as in the Adama case with induced learning. Consequently, the three experiences offer valuable perspectives on how the regulatory regime of the host nation might optimize the development advantages of Chinese investment opportunities. The autonomy of African governments from the influence of foreign actors is important in this respect (Gu, Zhang, Vaz, A., Mukwereza, 2016). Our case studies show that while African governments can influence co-benefits through negotiated contracts, their weak bargaining power may limit the scope of their influence on ensuring local development priorities in contract negotiations (Alves, 2013).

The industrial policy approach also influences the associated co-benefits, confirming insights in the existing literature (Baker and Sovacool, 2017; McCrudden, 2004; Power et al., 2016). The possibility of local capacity-building increases with a more purposeful and planned approach to participation. The wind project in Adama serves as the clearest illustration of this, as clear consideration was given to supply-chain, learning, and technology development throughout the contracting phase. In contrast, the Garissa project was carried out under a laissez-faire policy that resulted in few local jobs in the supply chain, few suppliers, and little interaction with a nearby university or research facility. In this instance, it could be argued that the project was a lost chance for REREC to concentrate on building local technical and skill capacities and/or fostering collaborations with local knowledge repositories to build capacities and fortify ties with local markets. A locally active policy stance and the application of existing bargaining power, even if low, is key. It is interesting to note that Kenya has subsequently adopted a more active policy approach and has embedded local content ambitions into the newly passed energy bill (Kingiri and Okemwa, 2021).

The significance of the relative strength of the domestic supply base and how it should be taken into account when choosing technology (as previously mentioned) were also highlighted by the three situations. Generally speaking, the availability of the necessary skills for complex project tasks in the design and execution of green energy infrastructure tended to limit local staffing across all scenarios. Arguably, this reflects a wider need for upgrading of engineering capability (Matthews, Ryan-Collins, Wells, Sillem, and Wright, 2012). A capability differential between local and foreign firms was apparent in cases where local firm with relevant profiles exists, but in many cases, there was no domestic supply base for several required functions. Our findings are aligned with the argument that co-benefits depend significantly on the capabilities of local firms engaged in green-technology manufacturing (Lema et al., 2015). As shown in Table 14, the manufacture of most core technologies and components is unlikely to take place in sub-Saharan Africa. However, there are a range of assembly tasks, as well as many services, that could be undertaken locally in the case of all three technologies examined here.

When making investment decisions, it may be beneficial to take a bottom-up approach to choosing projects and technologies. This involves taking into account both the activities that are in the zone of proximate development, or where realistic capability stretching may allow localization, such as assembling solar panels, and the range of activities that can be readily supplied locally, such as peripheral components like solar-panel racks or wind-turbine foundations. All three situations, however, point to the strategic importance of local participation in strategic services, including project management, as it expands the amount of opportunity to influence supply chain decisions. Therefore, it is crucial to establish roles and duties throughout the project execution stage through politically negotiated initiation negotiations, where discussions regarding funding may be discussed (Hanlin, 2019; Kirchherr and Urban, 2018). This may involve choice of technology and technology provider, as well as specifying the role of local actors and other conditions which have a direct bearing on the creation of co-benefits.

## 5.3 THE NATURE AND ORGANISATION OF THE INVESTMENT PROJECT

Our study demonstrated that the way a project is organized has a significant impact on the generation of economic co-benefits. As was already established, the nature of tied funding had the unintended consequence of causing Chinese EPCs to organize "bundled projects" in terms of contractual agreements. The terms set by the EPC contractors, the funding, and the project developers all had a clear impact on the architecture of the Adama project. CEB defined the technology's origin, but the technical equipment and suppliers show the preference for Chinese. Additional favorable terms were provided for the importation of equipment, including exemptions from taxes and customs charges. However, Ethiopia's government negotiated with state-owned shipping businesses and colleges to guarantee local participation.

Similar to this, the Bui project's organization was impacted by the turnkey EPC contract that placed Sinohydro in charge of both construction and operations. The Bui Dam project had about 60 relevant parties in total, and Sinohydro was in charge of both its implementation and supply chain management.

There were full-package EPC contract provisions in Garissa as well. The terms and conditions set forth by the financiers and the EPC contractors shaped the project's design. Additional advantageous terms were offered, including exemptions from customs charges and taxes, for imported equipment, including that which was not directly related to the project. The project was implemented mostly as a package that was "parachuted" in from China, which restricted the national actors' ability to exercise agency and influence (Bhamidipati and Hansen, 2021).

The importance of the financial component lies in the fact that it significantly increases the investor-contractor consortium's relative bargaining strength. Because of this, the co-benefits are primarily determined by the project developers who are involved in making the important choices related to the project. However, in project talks, there can be room for deliberate capacity-building. In the Garissa instance, the project offered organic, hands-on learning opportunities for skill development and acquainted a wide range of Kenyan stakeholders with the planning and functioning of a utility-scale photovoltaic plant. The beneficiaries included the employees of REREC, the Kenyan power companies KPLC, KenGen, and KETRACO, the five Kenyan engineers hired for O&M, and the Kenyan workers performing semi-skilled jobs. The training and acquisition of pertinent abilities (such as technical, electrical, IT, and safety-related skills) immediately benefited the engineers. In addition to finding temporary employment and pay, the unskilled Kenyan laborers carried out the kinds of jobs that are typical of most construction projects. However, the hiring of Maknes Consulting was a crucial step since it established a "vessel" for the transfer of local skills and knowledge from one project to the next. The possibility for co-benefits was however constrained by the project's overall turnkey model, which involved primarily Chinese contractors, the centralized style of project delivery, and the scant planned initiatives to boost local capacity building.

In order to increase technology transfer, the Ethiopian government used a similar approach but went one step further by granting universities the authority to serve as the owner's advisors. This was determined by the Adama case's particular organizational arrangements, which required knowledge transfer. The inclusion of universities as significant players in this scenario implies a desire to strengthen relationships between industry and higher education. It highlights how colleges might work together as recipients of information in the innovation system. Additionally, it highlights the roles that universities play in innovation systems, where a diverse range of actors who are not businesses play a significant role in building up capabilities. However, in practice, further studies need to be conducted to assess the quality of knowledge and technology transfer, as all parties in the Adama project mentioned challenges in the collaborative arrangements.

# CHAPTER 6

# CONCLUSION AND RECOMMENDATIONS.

This research project has set out to examine the type and nature of the local economic co-benefits that may arise from Chinese renewable-energy investments in sub-Saharan Africa. It contributes to a small but growing body of empirical research on the economic opportunities of implementing green transformations in latecomer countries. The existing literature on such economic opportunities (i.e. the potential co-benefits) has mainly focused on large ‘emerging economies’ with established programmes for renewable energy, comparably strong production and innovation systems, and the pre-existing potential for a high degree of localisation of green economic activities, and even for exports of green technologies (Binz et al., 2017; Lema et al., 2020). Much less attention has been paid to low- and lower-middle income countries where strategies and policies for greening with renewables are much more recent and where practical implementation is dependent on significant inflows of capital and technology.

The paper has sought to attend to this gap by focusing on specific renewable-energy investment projects in sub-Saharan Africa. Given the increasing Chinese involvement in renewable energy in this region, it was important to understand the extent, nature and determinants of the resulting co-benefits when projects are organised by Chinese renewable-energy developers. Since this push for co-benefits, although increasing, is still in its infancy, its insights are to be derived mainly from case studies of pioneer projects.

Additionally, China is now one of Africa's biggest financiers of energy infrastructure projects. However, the majority of studies on the effects of energy infrastructure supported by China only look at the harm to the environment and the relocation of nearby residents; very few have looked into the possible social and economic advantages that the region might have reaped from the infrastructure. This study examines the socioeconomic and environmental effects of the China-financed Bui Dam in Ghana using a case study approach that combines quantitative analysis with a qualitative literature assessment. EximBank, the project's primary funder, also plans to enhance its environmental standards and governance, as it has mandated since 2004 that borrowers subject to internal assessment and abide by local laws in the host nation. The OECD Arrangement is even highlighted by Eximbank in its lending procedures. Despite not undergoing an international bidding process, the Bui Dam project seems to have been constrained by global standards and conventions.

Two DiD models were employed in the quantitative examination of the social-economic effects of the Bui Dam. First, we contrasted the socioeconomic characteristics of every home in the four northern areas of Ghana, which get the majority of the power transmitted by the Bui Dam, with those of families in the other six regions both before and after the Bui Dam was completed. Next, we assessed whether there were differences in the degree of standard of living improvement between urban and rural households in the treated zones using a triple DiD model.

The Bui Dam has a statistically significant association with the improvement of all families' access to power, according to empirical data. Since the Bui Dam was built, there has been a 4.16 percent increase in the possibility that residents in the treatment regions will have access to power. The number of phones and cell phones owned by households rose dramatically. Even though the average number of households in the dam regions owned computers, refrigerators, and televisions decreased following the treatment, a breakdown of this negative coefficient into households with varying incomes reveals that, following the completion of the dam, the ownership of these appliances increased more quickly among poorer households than among control regions, while it did not increase as quickly among richer households. Given the relative cost of these high-wattage appliances in Ghana and the possibility that wealthier households own the majority of them, the slower rate of increase in the ownership of these items by wealthy households may have affected the overall rate of increase in the dam regions, resulting in a lower ownership rate of these pricey appliances by these households compared to the control regions.

When employing the triple DiD model, we discovered greater treatment effects on urban households. The likelihood of urban families having access to electricity increased by an average of 14.5%. Following the construction of the Bui Dam, they were 20.8 percent more likely to own TVs and 12.3 percent more likely to have refrigerators. Their ability to avoid malaria also improved when the probability of possessing mosquito bed nets rose by 10.3%. The lack of rural electrification infrastructure brought on by the last-mile issue may be the reason for the difference between urban and rural areas in the increase of living standards. An additional factor that may have contributed to the comparatively slower rise in rural high-wattage electric appliance ownership was migration from rural to urban areas and from the less developed northern regions (treatment regions) to the more developed southern regions (control regions).

Through a combination of quantitative and qualitative case analysis of Ghana's Bui Dam, this research aims to contribute to the ongoing observation of the socioeconomic repercussions of hydropower projects financed by China in developing regions, particularly Sub-Saharan Africa.

## MAIN FINDINGS AND RECOMMENDATIONS

The project-level analysis presented in Chapters 4 and 5 indicates that the initiatives under consideration contributed to the local economies to some extent; nonetheless, it is important to highlight how limited the advantages we found were. Therefore, we emphasize the need to exercise caution when it comes to having unrealistic expectations about the co-benefits of investments in renewable energy infrastructure projects in sub-Saharan Africa.

From a wider angle, the results of this study underscore the noteworthy obstacles linked to the concepts of sustainable industrialization and green latecomer growth in sub-Saharan Africa. Such a plan might be simpler to implement in upper-middle-income "emerging economies" when it comes to latecomer development. This study has provided insight into a variety of contexts where achieving goals that promote growth and development through extensive green infrastructure initiatives might be challenging. Geographical distance, unequal capability distribution, and imbalanced power dynamics between African green infrastructure developers and customers are some of the reasons behind this. In nations like Kenya, Ethiopia, and Uganda, this does not imply that green latecomer development should be dropped as a tactic. Instead, it indicates that it must be strengthened to become effective, at least when it comes to the provision of green energy infrastructure: a proactive and focused policy strategy must be developed to maximize the co-benefits of future investments in renewable energy. We relate the conclusions drawn from our research to three relevant policy concerns in order to further develop this understanding.

Firstly, even while there is evidence of benefits, they were not spontaneous outcomes of the investments, despite their restricted nature. The entire amount of available bargaining power must be used before making any green investment decisions. Local negotiating power is not nonexistent, although it is frequently limited.

African users and related local businesses and organizations in local production systems can benefit from the intentional transfer of knowledge and capabilities from current foreign suppliers of green infrastructure (Chinese or otherwise), as well as the maximum amount of local content and jobs in knowledge-intensive tasks. Even while this may seem apparent, there are signs that significant investment choices have been taken only with the principal benefits—lowering carbon emissions—in mind, with little consideration given to the strategic chances to realize the related economic co-benefits.

Secondly, these strategies and policies ought to intentionally concentrate on the possibilities that arise during the implementation of these green infrastructure initiatives. There is a propensity to overlook this phase in favor of an excessive emphasis on the methods of providing sustainable energy. For instance, the examined cases demonstrate that although training and overseas secondment resulted in sizable knowledge transfers pertaining to operations and routine maintenance (i.e., the service delivery process), there was no commensurately large and intentional transfer of capabilities pertaining to the previous infrastructure delivery process. Therefore, the goal must be the progressive development of local capacities associated with the latter. It is not enough, as is commonly said in investor and climate change circles, to claim that it makes no difference who builds the infrastructure as long as it is economical and environmentally friendly if the greening of local energy systems is to support local economic development. Our results suggest that only with strong local involvement in the more knowledge-intensive and high-value-adding phases of the infrastructure delivery process will there be significant co-benefits.

Thirdly, in this regard, green energy infrastructure shouldn't be viewed in a vacuum. The development of infrastructure project execution skills is crucial outside of this particular sector, such as when building roads, ports, energy distribution systems, etc., even if these kinds of projects have the potential to become significant learning and development platforms. It's interesting to note that independent local organizations were designated to serve as the owners' consultants in all three cases. These organizations may play a significant role in facilitating the local transfer of lateral competencies between projects. However, these talents may also need to be housed in government offices because of their strategic significance and national public-good nature.

# 7. APPENDICES

## Appendix A1: Explanatory variables

Additional details regarding the operationalization of the main explanatory variables are given in this appendix. Our strategy for gathering and analyzing data is displayed in Table A1, which supplements the data in Chapter 2.2.

**Appendix A2: Economic co-benefits**

The co-benefits and associated indicators shown in Table 2 of Chapter 2.3 are further discussed and explained in this appendix, which also provides the foundation for comprehending the empirical results shown in Chapter 4. It's crucial to remember that there aren't many standardized metrics that show how renewable energy projects affect local economy.

With theoretical minimum (or complete absence) and theoretical maximum (the full potential) levels, we conceptualize the three distinct co-benefit types attained in each project as a continuum in Fig. A2 below. We propose that a specific renewable energy project can be positioned at intervals or locations along the continuum. We go over each of the three co-benefits and associated metrics in the sections that follow, drawing from pertinent research.

Moreover, we were able to discuss and employ primary data on how China-Africa financial assistance on the hydropower projects, we acquired data regarding the hydropower project's lender and contractor, the overall amount of electricity installed, and the investment amount.

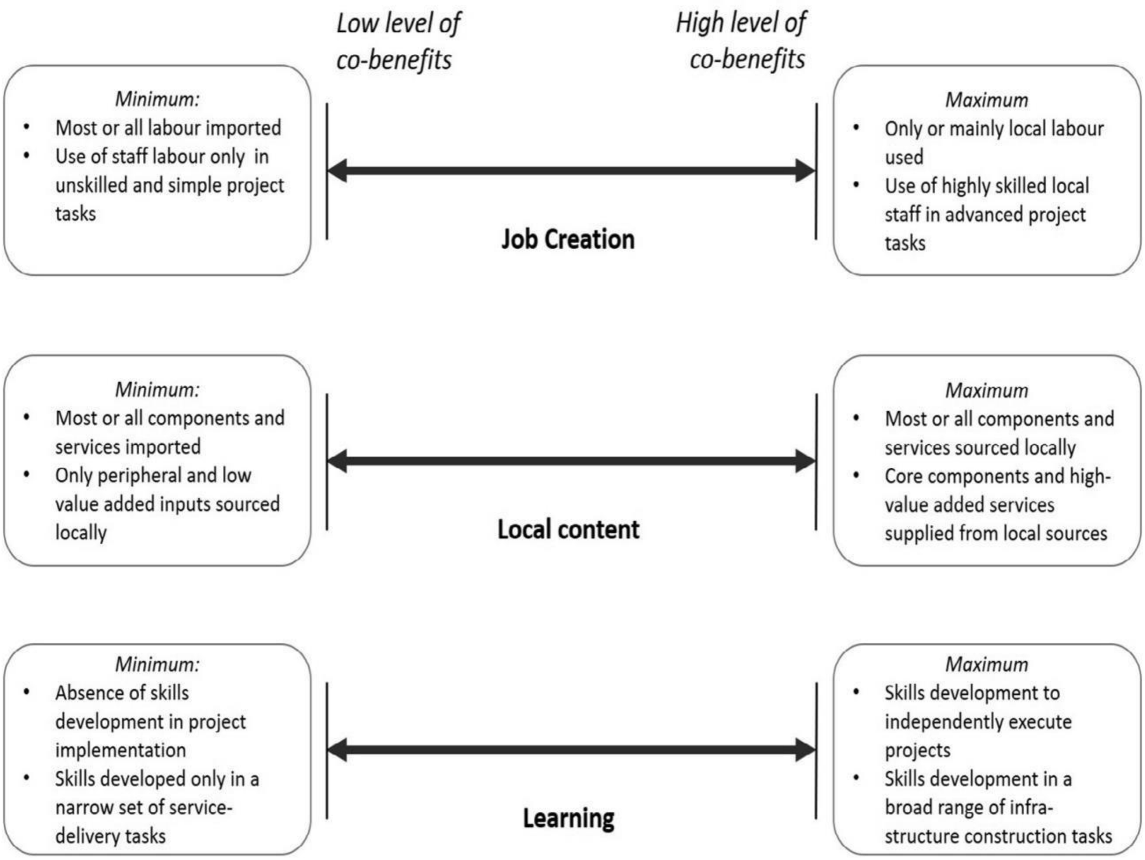
## Table A1

## Framework for data collection and analysis.

| Factor/unit of analysis | Components | Elaboration | Questions | Variability |
|---|---|---|---|---|
| A. Flows of capital and technology | A1: Lead agents involved. | The economic agent which drives the project; the location of the lead agent in the value chain. | Who was the most influential lead agent involved in the project? | - Financiers<br>- Project developers<br>- Technology suppliers |
| | A2: Nature of finance | The contractual arrangements specified at with the project finance deal | What was the nature of the financial arrangement? | - Competitive<br>- Tied finance |

| | | | | |
|---|---|---|---|---|
| | A3: Technologies and their components | The main choice of technology, design and the techno-economic characteristics of associated projects and services | Which technologies were used and what are their key characteristics? | - Manufacturing intensive<br>- Service intensive |
| B. Local institutional and economic conditions | B1: Deployment model | The deployment regime for renewables in the country and its bearings on the model adopted for project's selection and execution | Which deployment model was associated with the project? | - Competitive bidding<br>- Directly negotiated |
| | B2: Industrial policy environment | The industry policy approach to renewables and the consequences on the terms of the project | How can the industrial policy approach to the project be described? | - Laissez-faire<br>- Strategic |
| | B3: Local supply base | The extent to which local firms are able to undertake project functions at the time of project initiation | How strong were local firm capabilities vis-à-vis project functions? | - Weak<br>- Medium<br>- Strong |
| C. The nature and organisation of the investment project | C1: Contractual arrangements | The contractual arrangements specifying ownership and responsibilities in the different phases of the project lifecycle | What was the contractual arrangement? | - BOT project<br>- Turnkey project |
| | C2: Planned capacity building | The extent to which there was deliberate efforts of train local staff/firms and active efforts of knowledge sharing | What was the predominant approach to training and knowledge sharing? | - Active<br>- Passive |
| | C3: Project organisation | The project's 'anatomy' including the coordination and division of labour between local and foreign firms during the stages of the project life cycle | How was the project organised? | - Centralised<br>- Decentralised |

## Fig. A1. Continua of project co-benefits




Job creation has received more attention in the empirical literature compared to co-benefits of projects related to local content and learning. In order to assess the impacts of projects on job creation, we draw on literature on socio-economic development impacts of renewable energy, including recent reviews (IRENA, 2020; Jenniches, 2018). It is clear that job creation not only differs across technologies, but may also differ significantly across different projects within the same technology (Cameron and Van Der Zwaan, 2015). Research in this literature often distinguishes between employment in construction activities and operation using different indicators, such as total jobs per MW or total person-hours spent on specific projects (del Río and Burguillo, 2009). For this paper, we are specifically concerned with job creation in the local economy in relation to specific projects. As shown in Fig. A1, we conceptualise the minimum level of job creation to involve a project relying exclusively on imported labour without the involvement of any local workers at all.

We also consider the quality of the jobs created distinguishing between the use of low/unskilled labour at the minimum extreme and the use of highly skilled labour at the opposite end. Movement from the minimum level of job creation would then involve an increase in the share of local labour used in projects and an increase in the quality of the local jobs created (Pahle, Pachauri, and Steinbacher, 2016; Suberu, Mustafa, Bashir, Muhamad, and Mokhtar, 2013).

To address the impacts of projects on local content, we draw on literature on the local industrial development impacts of infrastructure projects in low-income countries in particular in sectors such as energy and extractive (Hanlin and Hanlin, 2012; Wells and Hawkins, 2010). Infrastructure projects are large-scale and capital-intensive and typically involves foreign investors, developers and technology suppliers from abroad. Literature generally shows that the share of local content in terms of locally sourced input materials, equipment and services can differ greatly across projects and technologies (Hansen, Nygaard, Morris, and Robbins, 2020). Local content can be measured, for example, as the share of the total value of a project spent locally or the number of components supplied by local firms (Tordo et al., 2013). Another indicator is related to the quality and value-added of the inputs sourced from local sources (Stephenson, 2016; Veloso, 2006). For this paper, the minimum level of local content denotes a situation where most or all of the input materials and services used in a project are imported. Hence, at the opposite end of the continuum, the maximum level of local content will involve a project, which relies exclusively on input materials and services sourced locally. Accordingly, a movement along the continuum toward the maximum level will involve an increasing number of local firms and other actors directly involved in a given project and/or an increase in the quality and value-added of the components and services provided by local actors. For example, local actors may at the lower end of the continuum only supply simply and peripheral materials, such as nuts and bolts and building materials, while at the higher end of the spectrum, local actors may supply more complex and core technology components (Schmidt and Huenteler, 2016).

To assess the impact of projects on learning, we draw on literature on learning and capability development in developing country firms and industries (Bell, 2012; Ockwell and Mallett, 2013), including the development of project capabilities (Davies and Brady, 2016; Matthews et al., 2012). In this literature, learning is understood as resulting in an increase in the ability of individuals and organisations to carry out working processes more efficiently and/or to implement projects with improved quality and complexity (Bell and Figueiredo, 2012; Hansen and Lema, 2019). The development and upgrading of human skills and cognitive resources are thus essential results of project-based learning (Bell, 2007; Park and Ji, 2020). For this paper, we conceptualise the minimum level of learning to involve a situation where there is an absence of skills development of workers involved in project-related activities. Furthermore, existing skills of the involved actors are applied only to a narrow set of tasks in the project cycle. At the opposite end of the spectrum, the involved individuals and organisations have developed the ability to carry out the implementation of projects independently, including manage the entire range of project activities. A movement toward the maximum level involves an increase in the depth of the qualifications of workers in project related activities and the broadening of the scope of involvement to across activities in the project cycle (from feasibility, planning, management, construction and operation).

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