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China's investments in renewable energy in Africa: Creating co-benefits or just cashing-in?

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ABSTRACT

Investments in renewable energy are increasing rapidly in sub-Saharan Africa. The overall purpose of this paper is to explore to what extent and under what conditions these investments are producing economic co-benefits in terms of spillovers and linkage development effects. One peculiarity of Africa's renewable-energy sector is the rapid increase and likely future growth of Chinese involvement in large-scale renewable-energy infrastructure projects. Insights from other infrastructure, utility and resource-extraction sectors in sub-Saharan Africa suggest that China is pursuing a specific Chinese model of investments characterised by enclave characteristics and including finance, turnkey project development and the importation of labour and equipment from China. Hence our focus in this paper is to determine to what extent economic co-benefits are created when renewable-energy projects are developed by Chinese investors. To do this, we undertake an in-depth analysis of three Chinese renewable-energy investment projects in hydro, wind and solar PV, based on primary data. Overall, we find evidence of 'bounded benefits'. On the one hand, we can identify some newly created jobs, linkages generated with actors in local systems of production and training activities involving local staff. On the other hand, the extent of these benefits is very limited. Overall, the results suggest that policymakers should be wary of overly optimistic expectations when it comes to assessing the co-benefits of renewable energy projects in the context of scarce pre-existing capabilities. However, the adoption of pro-active strategies and the implementation of carefully designed policies can increase the local economic co-benefits.

1. Introduction

The increasing demand for electricity will require a major expansion of the power system in sub-Saharan Africa. It is expected that electricity generating capacity will double over the next twenty years, with renewables accounting for three-quarters of new generation, the majority of that coming from solar, hydro and wind (IEA, 2020). Given the continuing shortage of energy in most African countries, the primary benefit of this expansion is electricity generation. Given the dominance of renewable energy in recent energy projections, reducing carbon emissions is also a primary benefit. While these benefits are indeed critical, recent literature on the drivers of investments in the green transformation has shown that the expectations of co-benefits are often critical for the support of green policies and practices (Dubash, 2013; Schmitz, 2017). The purpose of this paper is therefore to explore to what extent and under what conditions these massive investments in renewable energy have economic co-benefits. The additional benefits, beyond electricity generation and countering climate change, in sub-Saharan Africa 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).

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In this paper we focus on investments made by enterprises from the People's Republic of China (henceforth 'China') because it is the country which accounts for the single largest investment portfolio in ssub-Saharan Africa's power sector.[1] According to the International Energy Agency (IEA, 2016, p. 7), projects in which a Chinese firm is the main contractor alone account for 30% of new capacity additions in sub-Saharan Africa; of these projects, 56% are in renewable energy, with the vast majority being in hydro-power, but increasingly also in wind and solar energy.

Insights from other infrastructure, utility and resource-extraction sectors in sub-Saharan Africa suggest that China is pursuing a specific Chinese model of investments consisting of enclave characteristics, including finance, turnkey project development and imports of labour 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.

Despite 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 hydropower 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 devise a conceptual framework for the systematic comparison of project-level cases across different renewable energy technologies. While not providing statistical benchmarks, this paper introduces some conceptual and empirical reference points for future research – important in a field which suffers from dearth of in-depth analysis.

In order to push our knowledge in this respect, 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. However, before we proceed to these empirical parts of the paper, we seek insights from the relevant literature and provide a conceptual framework for the analysis.

2. International renewable energy investments and local development

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 aims to address this void by gathering insights about economic opportunities and developmental effects from case studies of frontrunner green-energy projects in sub-Saharan Africa. In this section, we outline a tailored conceptual framework for project-level analysis of the economic co-benefits associated with Chinese renewable-energy investments in Africa. The framework provides a heuristic analytical device aimed at exploratory empirical analysis.

2.1. Co-benefits of Chinese green-energy projects in sub-Saharan Africa

Our focus in this paper is on the concept of 'economic co-benefits' arising from Chinese renewable-energy investment projects in electricity in sub-Saharan Africa. 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.[2]

Fig. 1 presents our basic framework for explorative research. It aims to capture the main elements of the transnational investment–production complexes that envelope Chinese green-energy infrastructure investment projects and their economic co-benefits. The framework embodies the understanding that projects are shaped by both wider China–Africa relationships involving economic and political power and the local institutional and economic conditions, which may vary significantly between countries and cases.

A substantial part of our empirical analysis is focused on the extent and nature of these economic co-benefits, but we also seek to explore questions about their determinants. The key elements of this framework are discussed in the following.

2.2. Green-energy projects, investment-centred value chains and local institutions

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.[3] We discuss these in turn.

[1] As Shen (2020) emphasises, it is difficult to obtain a precise estimate of the size of and trends in Chinese activities in the power sector in sub-Saharan Africa. This reflects a larger problem regarding data shortcomings regarding funding from China because China has not released a breakdown of its lending activities (Horn, Reinhart, Trebesch, and Reinhart, 2020). We discuss the available data and its limitations in Section 3 of the paper.

[2] 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).

[3] The appendix A1 of this paper contains an expanded version of this table. It describes the corresponding key empirical questions and the key dimensions of variability.

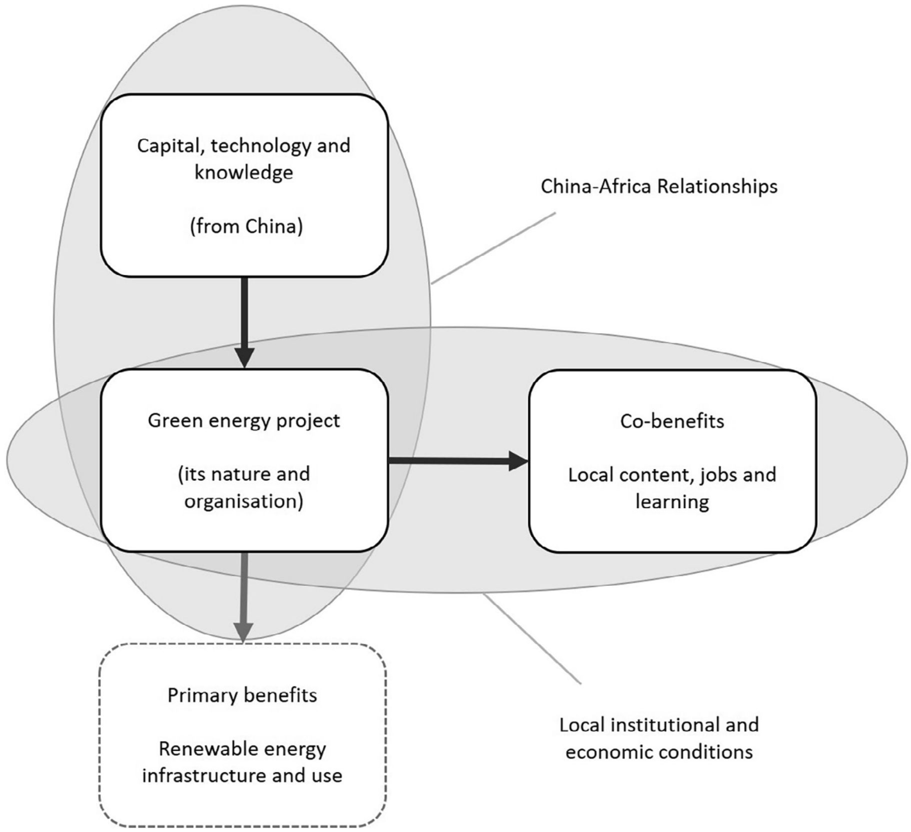

Fig. 1. Framework for exploratory research Note: the figure maps the key analytical building blocks examined in this study. Solid black arrows depict the main relationships in primary data collection and analysis.

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 - Lead agents involved - 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 - Industrial policy environment - Domestic supply base	(Baker and Sovacool, 2017; McCrudden, 2004; Power et al., 2016)
The nature and organisation of the investment project	- Contractual arrangements - Planned capacity-building - Project organisation	(Hanlin, Okemwa, and Gregersen, 2019; Hansen et al., 2018)

2.2.1. 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 consortiums. 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. Table 1 lists the key variables of the flows involved in such global investment chains, from the specific technology used via the types of capital transferred to the roles of both lead agents (firms governing these chain interactions) and finance.

2.2.2. 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). Insti-

Table 2
Key co-benefits and indicators.

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

tutional 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). Generally, there is a move toward the use of competitive bidding systems worldwide due to their ability to reduce prices and ensure transparency. However, as Shen has pointed out (2020), directly negotiated contracts are the preferred mode of entry for Chinese investors in the renewable-energy sector in Africa compared to open bidding systems, such as auction schemes.

2.2.3. The nature and organisation of the investment project

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). Engineering, procurement and construction (EPC) contracts are awarded to a single firm, which then sub-contracts numerous tasks in the contract to product and service suppliers, while overseeing overall project management itself. Hence the empirical challenge is to dissect different variations of project 'anatomy' in the contractor-driven model. In this respect, it is useful to distinguish between anatomies involved in, respectively, investment project infrastructure delivery (the plant) and service delivery (use of the plant for electricity provision). A third element is the degree of planned capacity-building. The EPC contractor is frequently contractually obliged to build up the necessary capacities in the awarding entity to ensure it can operate the asset and provide the service once the contract ends. In principle, such deliberate capacity-building initiatives may extend to the delivery of the infrastructure itself.

In sum, the outcomes reflect a multitude of technological, economic and political factors in specific China–Africa relationships. Together, global flows and local conditions influence the nature and organisation of the investment project, which may in turn leave different degrees of scope for the realisation of economic co-benefits. As a framework for exploratory analysis, we deliberately seek to reduce complexity while as the same time being cognizant of the fact that the expansion of green energy is a highly contested and political process, as exemplified by the vertical and horizontal ellipses in Fig. 1.

2.3. Economic co-benefits

We examine three main types of co-benefit: employment, local content and technological learning Table 2).[4] Since the core of our empirical analysis is concerned with benefits, it is important to specify these further:

2.3.1. 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 may be generated at different steps in the chain, such as project construction, operation, maintenance or other project services. Jobs across these functions may require varying degrees of skill and knowledge intensities.

2.3.2. 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).

2.3.3. Technological learning

The degree to which local firms and related actors can use investments in renewable energy to develop their own technolog-

[4] The concern with what we have called 'economic co-benefits' has a long history in development economics. Much of it was conducted using the externalities and linkages frameworks (Hirschman, 1958; Scitovsky, 1954) which highlighted the importance of economic co-benefits but struggled with rigorous measurement and comparison. In addition, literature on technology spillovers, transfer and capability building (Blomström and Persson, 1983; Lall, 1974; Stewart, 1977) became prevalent in the 1970s and has recently seen a revival. We bring these concepts together under the co-benefits heading in order to increase the relevance of the analysis for the climate policy and green latecomer development discussion.

ical and organisational capabilities is important because it raises the prospects that these firms' actors can, over time, increase their competitiveness and their ability to undertake activities involved in future green investments and related areas. 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 depends on the nature of the knowledge flows, such as whether knowledge is embodied in machinery and equipment or whether it involves transfers of people-embodied knowledge, e.g., through site visits by the technology supplier or training visits by the technology recipient.

It is important to note that types and quantities of these economic co-benefits are not easy to measure in an exact way. Moreover, once an empirical exploration has taken place it is difficult to assess whether identified co-benefits are few/shallow or many/deep. This is because such an assessment can only be made in relation to other studies of a similar nature (which are few and far between) as well as in relation to a theoretical maximum of co-benefits that could ideally arise. To address this issue, we provide Appendix A2 which describes our composite indicators and helps to situate and interpret our findings.

2.4. Research design and case selection

For the purposes of this research, the potential co-benefits and their determinants were examined by means of the conceptual framework outlined above. We chose a case study approach for this research as it involves exploratory research on a contemporary phenomenon that has not been previously examined in detail (Yin, 2013).

Cases are typically chosen as examples or representatives of a wider phenomenon. The wider phenomenon of interest in this paper is Chinese investment in Africa's renewable-energy sector.

Hence, we focus exclusively on China's involvement in the renewable energy sector in Africa (the research object) and we do so by focusing on investment projects (the unit of analysis), which is the typical mode of organisation in the green energy sector. Accordingly, for the purposes of this research, renewable-energy projects should have in common the fact that they all include Chinese finance and Chinese project management. 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).

Taking our point of departure in this strategy, projects were chosen using three different 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).[5] 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).

The core of our analysis thus builds on primary data obtained at the project level. This information was used for micro-level analyses exploring inbound flows, local conditions, the characteristics of organisational arrangements and the three main types of co-benefit. The main sources of information for these case studies are site visits at each project and a total of 38 in-depth interviews with project organisers and key informants with relevant knowledge of each project. Section 4 includes notes with further information about data collection in each case.

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).

3. China's involvement in renewable energy deployment in sub-Saharan Africa

This section provides an overview of China's involvement in renewable energy deployment in sub-Saharan Africa in relation to the three technologies discussed in this article. Discussing the patterns of capital and technology flows from China allows us to examine the macro-evidence for the existence of a 'Chinese model' of green-energy investments. The purpose is to provide a backdrop for the project-level analyses in subsequent sections.

3.1. China's overall role in the energy sector in sub-Saharan Africa

As already mentioned, 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
Hydropower	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).

[5] 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 hydropower dams are significant, as they have been found to harm fisheries and related livelihoods; the construction of hydropower dams has replaced more than eighty million people in the past century (Kirchherr and Charles, 2016). Despite these vast negative impacts, a hydropower surge is still under way, with more than 3,700 dams either planned or under construction (Zarfl et al., 2015).

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) • Chinese Development Bank (CDB) • Sinosure • Industrial and Commercial Bank of China (ICBC) • Bank of China (BoC)	• Sino Hydro • PowerChina Resources • Three Gorges Corporation	• Dongfang Electric Corporation • Harbin Electric Corporation • Shanghai Electric Power
Wind	As above	• CGC Overseas Construction Group • Hydro China • Longyuan Power Group	• Goldwind • Sany • Sinovel
Solar	As above	• China Jiangxi Corporation • Powerway • Beijing Xiaocheng	• JinkoSolar • Yingli • JA Solar

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

Table 3 shows the installed capacity in sub-Saharan Africa across the three energy sources in 2009 and 2018 respectively. In the hydropower sector, Chinese investors accounted for 60% of investments in sub-Saharan projects. As is shown below, the Chinese are also significantly involved in both the solar PV investments – which surpassed investments in hydropower 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 remainder of this section analyses the role of various Chinese actors in the development of hydropower, solar PV and wind-power projects, focusing specifically on (i) financial institutions, (ii) EPC contractors and (iii) technology providers.

3.2. Financial institutions

In terms of flows of financial capital in renewable energy from China to Africa, the Export-Import Bank of China is by far the main investor in projects constructed by Chinese contractors, providing finance to more than 60% of the projects analysed in IEA (2016). The main investment model is based on preferential loans and export credits provided to project developers. In addition, direct equity-based investments, commercial loans and grants are also provided, in particular from the financial institutions mentioned 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 HydroChina Corporation, a subsidiary of PowerChina (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).

Financial institutions are powerful actors in the transnational investment–production complexes in which green-energy infrastructure projects are embedded, and they may specify 'foreign content requirements' involving Chinese EPC and technology providers as a part of financing deals.

3.3. EPC contractors

Table 4 also provides examples of EPC contractors across the three technologies. The main Chinese investors involved in renewable-energy projects in sub-Saharan Africa typically include large state-owned enterprises (SOEs): 90% of the power projects analysed in IEA (2016) are being contracted and constructed by Chinese SOEs, which include companies such as the State Grid Corporation. The remaining 10% of these projects are being constructed by private Chinese developers specialising in large-scale infrastructure, construction and civil-engineering projects in the energy sector.[6]

In the area of hydropower projects in sub-Saharan Africa, prominent Chinese EPC contractors include leading Chinese dam-builders, such as Sinohydro (also known as PowerChina) and the China Three Gorges Corporation. These Chinese dam-builders are internationally renowned for their hydropower engineering skills and expertise (Kirchherr and Matthews, 2018). The Bui dam was constructed and operated by Sinohydro under an EPC turnkey contract and went into operation in 2013. An increasing number of leading Chinese EPC contractors have been involved in wind-power projects constructed in sub-Saharan Africa, not least in South Africa, Kenya and Ethiopia. Sometimes leading Chinese wind-turbine suppliers, such as Goldwind and Sinovel, also operate as EPC contractors. HydroChina was the EPC contractor in the Adama wind-power project in Ethiopia. In solar PV, Chinese companies were often engaged as suppliers and technology providers rather than as EPC contractors (IEA, 2016), but given the growth in grid-scale projects this is now changing. The Garissa project was constructed by the Chinese EPC contractor China Jiangxi Corporation for International Economic and Technical Cooperation (CJIC).

As already mentioned, under EPC contracts, Chinese developers are responsible for all aspects of the project, from the initial feasibility stage via plant engineering and the subcontracting of components and related services to the plant's final commissioning. EPC is thus instrumental in selecting technology providers.

3.4. Technology providers

Given an increasingly saturated domestic market and fierce competition in the European and US markets, Chinese technology-producing companies, such as those mentioned in Table 3, have increasingly moved into sub-Saharan Africa (Shen, 2020). Table 5 draws on the latest data to show the changes in exports of renewable-energy technology from China to sub-Saharan Africa over two five-year periods. There have been mas-

[6] Five of these companies combined are responsible for three-quarters of the total generating capacity added Chinese developers between 2010 and 2015 in SSA (IEA, 2016).

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

sive increases in exports since 2010 in all three sectors. Hydro-technology exports and imports are relatively low compared to wind and solar because core technology only constitutes a relatively small share of the overall capital expenditure in hydro projects. However, China–Africa trade in hydro-technologies like turbines more than tripled in the second five-year period when compared to the first. Nonetheless this increase is nothing like as dramatic as the increase in wind and solar, both of which are growing exponentially. These data show how recent a phenomenon the trade in renewable energy from China to Africa is and how quickly it is growing. The export of hydropower turbines from China to Africa is closely connected to specific hydropower 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 summarise, the increasing influence of China in the renewable-energy sector in sub-Saharan Africa can be observed across the three renewable-energy sub-sectors analysed in this article. Chinese actors, such as investors, EPC turnkey contactors and technology suppliers, are responsible for providing key financial and technological resources in various renewable-energy projects in the region. Interestingly, we see a tendency for Chinese investors and contactors to supply projects on a turnkey basis delivered as a bundled package comprising a considerable representation of Chinese investors, engineering companies and technology suppliers. The picture that emerges is thus one of increasing Chinese market share and a dominant pattern of full-package provision.

A possible reason for the development of this Chinese model may be the nature of China's funding-support requirements, which stipulate that investors are eligible for export credits only if the equipment used is manufactured in China. While this model resembles the traditional Western 'tied-aid' approach in development cooperation, the Chinese version differs significantly from it because of the dominance of state-owned enterprises and the bundled nature of the projects.

4. Insights from the three projects

This section draws on primary data to examine the key factors and indicators developed for this analysis (in Section 2). Three sub-sections describe 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. The Adama wind project

The Adama wind-power project consisted of two phases of planning and construction by a joint venture between Chinese turn-key contractor HydroChina and the CGCOC group, a Chinese construction company, for Ethiopian Electricity Power (EEP), the project owner.[7] The EPC contract thus included the design, manufacture, supply, installation-testing and commissioning of the project, including all ancillary work and civil works. The first phase included the installation of 51 MW of wind power and was finalised in 2012. For the second phase, Adama II, a total of 102 turbines were installed. The 153 MW project was commissioned in 2015.[8]

The types of *jobs* created in the Adama project are directly linked to the financing agreements, which specified that Chinese technology was to be used in the project. The turnkey contract held by HydroChina-CGCOC covered the majority of the value chain for the project, from its design and construction to handover training. Local jobs in project construction were the responsibility of HydroChina and totalled a thousand across the two phases of the project compared to approximately four hundred jobs held by Chinese employees. The contract between EEP and HydroChina stated that unskilled labour should be recruited locally and that using staff and skilled labour with the required qualifications and experiences from sources within Ethiopia was to be encouraged. 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.

Local content in the project was limited to the minimum involvement of local firms in the supply mainly of construction materials such as concrete, while the state-owned shipping company was involved in the transportation of wind-turbine components. All imported equipment, materials and construction equipment were exempt from customs duties, value added tax, and additional taxes. Furthermore, there was only minimal involvement by local communities in respect of deciding compensation for the temporary and permanent loss of farmland in order to build the wind farms and the necessary access roads. Beyond the access roads and water pumps, other social development projects were not deemed to be required. HydroChina held multiple information sessions and seminars to educate local residents on the impacts of wind farms.

In respect of *technological learning*, the investment model, designs and blueprints for the project were developed independently by HydroChina and CGCOCC. All permanent equipment for the project was sourced and imported from Chinese companies as 'black-box' components – the unit transformer, 33KV cabinet,

[7] Primary data for the Adama case were gathered in November 2017 through eleven key informant interviews with key stakeholders. Fieldwork included a site visit, and informants included project managers, engineers, consultants and policy-makers. In addition to publicly available sources, recent studies by Chen (2016; 2018) analysing technology transfers in both the Ashegoda and Adama wind-power projects in Ethiopia provided further useful information, in particular on the number of jobs created and information sessions for local communities.

[8] Phase I was completed using a Goldwind direct-drive wind-turbine model, while phase II was completed with a gear box model from Sany.

Table 6
Overview of the projects: actors and roles.

Capacity and ownership		Adama	Bui	Garissa
Ownership and Capacity	*Owner/sponsor*	Ethiopian Electricity Power	Bui Power Authority	Kenya Rural Electrification Authority
	Energy source	Wind	Hydro	Solar PV
	Size	204 MW	400 MW	55 MW
	Cost	USD 462 million	USD 560 million	USD 140 million
Infrastructure delivery	*EPC and project management*	HydroChina and CGC Overseas Construction Group	Sino Hydro	China Jiangxi Corporation for International Economic and Technical Cooperation (CJIC)
	Finance	Export-Import Bank of China (85%) and Government of Ethiopia (15%)	Export-Import Bank of China (89%) and Government of Ghana (11%)	Export-Import Bank of China (100%)
	Front-end and detailed engineering	HydroChina and CGC Overseas Construction Group	Coyne et Bellier (France) and Sino Hydro	CJIC and Maknes Consulting
	Core technology supply	Goldwind (China) and Sany (China)	Produced in China by Alstom (France)	JinkoSolar (China) and BYD (China)
Service delivery	*Electricity Distribution*	Ethiopian Electric Services (EES)	ECG/Gridco	Kenya Power and Lighting Company
	Plant operation	Ethiopian Electricity Power	Bui Power Authority	Kenya Electricity Generating Company and CJIC
	Plant Maintenance	Ethiopian Electricity Power	Sino Hydro	KECG

main transformer, circuit breaker, grounding transformer, SCADA system and communication equipment – which constrained local learning. 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.[9] 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.

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 HydroChina 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.

4.2. 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.[10] 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)[11] upon completion of the project.

Formally, strategic oversight of the project lay with the Ghanaian 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's 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 Ghanaian, 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

[9] The terms of reference for the consultants explicitly state that the aim is to ensure technology transfer specifically in: (a) building the capacity to implement construction contracts with foreign technologies, (b) building the capacity to manufacture main components such as towers and blades, and (c) eventually building the capacity to manufacture most of the components and this develop own technology. The team was from three Ethiopian universities, Addis Ababa University in phase I and Adama Science and Technology University (ASTU) and Mekelle University (MU) in phase II).

[10] This case study is based on eighteen interviews undertaken with Chinese and Ghanaian informants over a six-month period. Interviews were semi-structured and conducted with relevant stakeholders from the public sector, the private sector and civil society. These data were complemented by a review of more than a hundred newspaper articles on the Bui Dam dating from 2001 to 2020. The research also benefitted from prior research into this case (Hensengerth, 2018; Kirchherr, Disselhoff, and Charles, 2016).

[11] Previously, the French consulting firm Coyne et Bellier had produced the dam design, and the British consultancy Environmental Resources Management (ERM) had conducted the Environmental and Social Impact Assessment (ESIA).

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 Ghanaian 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.

With 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 hydropower 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 Ghanaian 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 Ghanaians. Deliberate knowledge transfers related mainly to operational tasks during the construction phase, with Ghanaian 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.

To *summarise*, 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 Ghanaian 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 Ghanaian 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.

4.3. 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.[12] 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.[13] 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.[14]

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 installa-

[12] Primary data for the Garissa case were gathered in October 2017 from nine key-informant interviews and one focus-group discussion with local stakeholders. Fieldwork included a two-day site visit, and informants included Chinese project managers, workers, and the project liaison officer in Garissa County. Additional interviews were held in Nairobi with REA and EPRA staff. In addition to publicly available sources, a recent study by Hanlin (2019) conducted during the O&M phase of the project provided useful information, in particular on actual jobs created and skills involved in the O&M phase.

[13] Early on, promises and assurances were made regarding the total jobs the project would generate, at least 1000, as reported by various media outlets quoting REA leadership. In reality, the total number of jobs created was much lower than promised.

[14] Their O&M tasks include system inspections, monitoring the grid, highlighting faults in the sub-station etc. Furthermore, additional local employment during O&M is to be generated in the form of security guards, solar-panel cleaners and general cleaners for the project site spread over 85 ha.

tion 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 invertors, 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 policymakers 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.

5. Economic co-benefits and their determinants

The three projects differ significantly in their technical nature, but by drawing on the frameworks set out in Section 2, it is possible to bring them to together for analysis and comparison. In this final analytical section, we start by providing an overview of the identification of co-benefits before proceeding to an explorative discussion of the determinants of these benefits.

5.1. Economic co-benefits

Table 7 summarises key information regarding the various types of co-benefits. Overall, we find evidence of bounded co-benefits accruing to the local economies. Overall, benefits were 'limited'. When using the term limited, we mean that the level of a specific co-benefit identified in a project is close to the minimum endpoint of one of the three continua described in the Appendix A2 to this paper. Conversely, when referring to 'significant', this is to denote a project that is close(r) to the maximum level at the opposite end of the spectrum. It is important to note, however, that each of the three types of benefit has more than one indicator (they are composite indicators) and that there may be differences within them.

Direct job creation was significant but varied throughout the project's phases. In the construction phase the projects were dominated by local staff, with locals constituting 70–90% of total project employers. However, in terms of job functions, with few exceptions, highly skilled activities were mainly carried out by Chinese nationals, with most local jobs confined to semi-skilled or low-skilled activities. In the operational phase, with fewer but more permanent jobs, the key tasks typically involved a phased handover from Chinese to local staff. The creation of backward linkages from the projects through the provision of local service and manufacturing inputs from local firms was a feature of all three projects but was limited. These linkages tended to be confined to peripheral and non-critical components or services. Core components were almost exclusively imported from China or, alternatively, sourced from specialised suppliers in advanced economies. Both the nature of the jobs and the (limited) involvement of local suppliers also has ramifications for the opportunities for technological learning. In general, the domain in which the most significant capability-acquisition and 'knowledge transfers' from China took place was the operational phase of projects (i.e. the service delivery process), involving operational skills and know-how, as well as minor maintenance capabilities. Much less learning occurred in the economically important construction phase (i.e. the new green infrastructure delivery process). However, as we will see below, there was some interesting experience-acquisition related to the non-trivial area of project management and the oversight of technical processes in networks involving local sponsors (ministries of energy), engineering consultants and technical universities. In sum, the use of local manpower was significant, but the use of local manufacturing and services and the development of local expertise capabilities, although detectable, was rather limited.

Overall, across all projects there is evidence of some local content provision, job creation and learning. However, these co-benefits only seem to be 'significant' in respect of specific indicators: most significant benefits did not extend to local content and learning in strategic functions. We discuss these findings below, guided by the analytical framework in Section 2. This helps us shed light analytically on the preconditions and mechanisms of co-benefit creation. It shows that the key factors that influence outcomes are relative bargaining power, overall project design, degree of upfront planning of benefits and policy arrangements.

5.2. The nature of inbound flows of capital and technology from China

As shown in Table 8, 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 *nature of the technologies* used in the projects had important implications for the creation of co-benefits. They differ greatly with respect to labour intensity, capital requirements and complexity, all which have important bearings on co-benefits. Although based on just a few cases, this insight aligns with the literature on the sectoral characteristics of green technologies, suggesting that industry localization effects are highly technology-specific (Schmidt and Huenteler, 2016). In other words, the scope and nature of the co-benefits depend on given technical characteristics. For example, the relatively high degree of local content in the Bui case can be explained by the high transportation costs of cement for construction and the need to produce the cement on site. This suggests that choice of technology should feature high on the agenda in

Table 7
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 consultants.	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 bootcamps for workers working on the construction site.	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 O&M.

Table 8
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 HydroChina-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 windfarm 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 hydropower 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 HydroChina-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.

deliberations about greening and that these discussions need to take into account key 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).

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 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 HydroChina/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.

5.3. Local institutional and economic conditions

The analysis also suggests that local conditions – local deployment models, industrial policies, the domestic supply base and local capabilities – significantly influence the nature of project and associated co-benefits. In continuation of the points made in the prior sub-section, it is relevant to note that the projects analysed were negotiated in the context of weak institutional regimes, or even 'institutional voids' (Silvestre, 2015), when it comes to the *host economy deployment policy model* for renewable energy. This meant that projects were negotiated 'ad hoc' even when there was a feed-in tariff policy in place, which was eventually circumvented (the Garissa case), or there were initially intentions regarding local content, which ultimately could not be met (the Bui case).

The policy stance is a key variable and can make the difference between 'naturally occurring co-benefits' and 'induced co-benefits'. The majority of identified co-benefits are of the former type (e.g. sourcing local cement in the case of hydro), but some case material also points to the latter occurring, such as induced learning in the Adama case. As a result, the three cases provide insights into the role of the host country policy regime in maximizing the development benefits of Chinese investment projects. 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 (see also Alves, 2013).[15]

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). A more deliberate and strategic form of engagement means a greater likelihood of local capacity-building. The best example of this is the wind project in Adama, where explicit attention was paid to technological, learning and supply-chain development during the contracting stage. As a counterpoint, the Garissa project was implemented in the context of a laissez-faire regime that entailed limited local jobs in the supply chain, limited suppliers and hardly any engagement with a local university or research institute. In this case, the project could be viewed as a missed opportunity that REREC could have utilized specifically to focus on enhancing local skills and technical capacities, and/or supported synergies with local knowledge repositories to develop capacities and strengthen the linkages with local industries. 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).

Furthermore, the three cases emphasised the importance of *the relative strength of the domestic supply base* and how this needs to be considered in relation to the choice of technology (as discussed above). In general, across the cases, local staffing tended to be constrained by the availability of the relevant skills for advanced project tasks in green energy infrastructure design and delivery. 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 8, 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.

Investment decisions may benefit from a bottom-up approach to the selection of projects and technologies, considering first the range of activities that can easily be supplied locally (e.g. peripheral components such as solar-panel racks or wind-turbine foundations) and secondly those activities that are in the zone of proximate development, that is, where realistic capability-stretching may enable localisation (e.g. assembling solar panels). However, the three cases all suggest that local involvement in strategic services, not least project management, is strategically important because it creates greater scope for influencing decisions concerning supply chains. Hence, the politically negotiated initiation stage of projects, where negotiations around financing may specify roles and responsibilities during the project-execution stage, is key (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.

5.4. The nature and organisation of the investment project

Our research showed that project organisation has important implications for economic co-benefit creation. In terms of the *contractual arrangements*, as mentioned already, the nature of tied finance had the knock-on effect of creating 'bundled projects' organised by Chinese EPCs. In Adama, the project was clearly designed and influenced by the project developers, the financing and the EPC contractors' terms. The origin of the technology was defined by CEB, while the suppliers and technical equipment illustrate the preference for Chinese. Further favourable conditions were granted to the importation of equipment, with exemptions from both customs duties and taxes. However, negotiations on the part of the government of Ethiopia were designed to ensure local participation through the involvement of the universities and state-owned shipping companies.

[15] In terms of civil society, we found no evidence of important influence during contract negotiations, technology choices and planning stage of projects but some evidence that local communities have influenced projects in the later stages of the project cycle (e.g., site selection, and project implementation aspects).

Similarly, in the Bui project, the turnkey EPC contract that put Sinohydro in charge of its construction and operations had implications for the *project's organisation*. Some sixty relevant players were involved in the Bui Dam project overall, with Sinohydro responsible for its implementation and for organising its own supply chains.

In Garissa too there was a full-package provision of EPC contracts. The project was designed and influenced by the EPC contractors and the financiers' terms and conditions. Further favorable terms were provided for imported equipment (including those not directly related to the project) with exemptions of both custom duties and taxes. To a large extent, the project was executed as a package 'parachuted' in from China, which limited the agency and influence that could be exerted by the national actors (Bhamidipati and Hansen, 2021).

The element of finance is significant because it shifts the relative bargaining power strongly in favour of the investor–contractor consortium. As a result, the co-benefits are largely dependent on the project developers that are engaged in making the key decisions concerning the project. However, there may be some scope for *planned capacity-building* in project negotiations. In the Garissa case, the project provided naturally occurring, learning-by-doing opportunities for skills development and for familiarizing a host of Kenyan stakeholders with the design and operation of a utility-scale PV project. The beneficiaries included REREC staff, Kenyan electricity firms (KPLC, KenGen, KETRACO), the Kenyan workers engaged with semi-skilled tasks and the five Kenyan engineers hired for O&M. The engineers benefitted directly from the training and acquisition of relevant skills (including technical, electrical, IT and safety-related skills). The unskilled Kenyan workers secured temporary jobs and incomes, but they also performed the sorts of tasks that are generic to most construction projects. Importantly, however, the engagement of Maknes Consulting was an important step because it created a 'vessel' for the transfer of local capabilities and lessons from one project to the next. Nonetheless the overall turnkey model of the project involving mainly Chinese contractors, the centralized nature of project delivery and the limited planned efforts to increase local capacity-building limited the scope for co-benefits.

The government of Ethiopia utilised a similar strategy but went further in its decision to give universities the mandate to act as the owner's consultants with the aim of increasing technology transfer, as knowledge transfer defined the unique organisational arrangements of the Adama case. Bringing in universities as important actors in this situation suggests the intention to develop industry-university linkages. It emphasises how universities can act as one as recipients of knowledge transfers in the innovation system. It also accentuates universities' roles in innovation systems, where a heterogeneous group of actors that are not firms are important in contributing to capability accumulation. 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.

6. Conclusions and policy issues

This paper 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.

6.1. Main findings and policy implications

The project-level analysis described in Sections 4 and 5 suggests that the projects examined here made some contributions to the local economies, but it is necessary to emphasise the highly restricted nature of the benefits we identified. Hence, we stress the need for caution when it comes to overly optimistic expectations of co-benefits arising from investments in renewable-energy infrastructure projects in sub-Saharan Africa.

In a broader perspective, the findings of this paper highlight the significant challenges associated with the notion of green latecomer development and sustainable industrialisation in sub-Saharan Africa. In the context of latecomer development, such a strategy may be easier to achieve in upper-middle-income 'emerging economies.' This paper has shed light on substantially different settings, where growth and development-enhancing objectives are rather difficult to achieve through large green infrastructure projects. This is not least because of the geographical separation, unequal distribution of capabilities and skewed power relations between the users and producers of green infrastructure in Africa.

This does not mean that green latecomer development should be abandoned as a strategy in countries like Kenya, Ethiopia and Uganda. On the contrary, it means that, at least in the context of the provision of green energy infrastructure, it needs to be stepped up to become effective: an active and directed policy approach needs to be devised for maximising the co-benefits of further renewable energy investments in the future. To unfold this insight further, we connect insights from our findings with three pertinent policy issues.

First, while we find evidence of benefits, these benefits, however limited, did not emerge as automatic by-products of the investments. Every green investment decision needs to be preceded by exerting the full extent of the available bargaining power. Local bargaining power is often constrained, but it is not non-existent. This can ensure the maximum possible local content, jobs in knowledge-intensive tasks and deliberately designed transfers of knowledge and capabilities from existing foreign suppliers of green infrastructure (Chinese or otherwise) to African users and associated local enterprises and organisations in local systems of production. While this point may seem obvious, there are indications that major investment decisions have been made mainly with the primary benefits in mind (i.e. reducing carbon emissions) and without paying sufficient attention to the strategic opportunities to achieve the associated economic co-benefits.

Second, these policies and strategies should focus deliberately on opportunities in the process of delivering these green infrastructure projects. There is a tendency to neglect this stage while focusing too much on the processes of delivering sustainable energy. For example, the cases analysed show that, while there were quite significant transfers of knowledge through training and overseas secondment related to operations and routine maintenance (i.e. the service delivery process), there was no correspondingly significant and deliberate transfer of capabilities related to the preceding infrastructure delivery process. Accordingly, the ambition needs to take the form of the gradual building of local capabilities related to the latter. If the greening of local energy systems is to be beneficial to local economic development, it is not sufficient to say, as is sometimes done in investor and climate change circles, that it does not matter who creates the infrastructure as long as it is green and cost-efficient. Our findings indicate that significant co-benefits will only arise with substantial local involvement in the high value-adding and more knowledge-intensive stages of the infrastructure delivery process.

Third, green energy infrastructure should not be treated in isolation in this respect. While these types of projects could become important learning and development platforms, the attainment of infrastructure project execution capabilities is relevant outside this specific domain, that is, in building roads, ports, electricity distribution systems etc. as well. Interestingly, in all three cases independent local entities were assigned to the role of the owners' consultants. These entities could become important vessels for local transfers of lateral capabilities from one project to the next. However, due to the strategic importance of these capabilities and their national public-good nature, they may also need to be located in government offices.

6.2. Future research

The research in this article was exploratory in nature, using an approach which sought to seek insights from projects with significant variation in terms of the technologies used and local contextual conditions. While this enabled an initial in-depth analysis of the co-benefits of specific Chinese projects, the approach also has limitations with respect to the generalisability of its findings. Future research should address these limitations by examining both the generalisability of the findings and their specificities. In this respect, it is interesting to note that the discussions regarding the dynamics underlying Chinese loan-based funding for renewable energy projects in this paper are very similar to the dynamics unveiled by Kaplinsky and Morris (2009) regarding Chinese FDI in general and large infrastructure projects in particular. They emphasise the way Chinese FDI in Africa bundles together loans, FDI and trade, producing a specific 'Chinese model' of investment and supply-chain management. As such, our findings indicate that such patterns are also replicated in renewable energy investments. But are the fears of exploitative enclave development, which is sometimes found in the China in Africa literature, warranted or overstated in the case of renewables? This research has provided some baseline findings which can be used for more systemic analyses of this question.

In continuation of this point, recent research has indicated that Chinese business models are markedly different from how Northern lead firms govern their investments and value chains in sub-Saharan Africa (Kaplinsky and Morris, 2009; Wegenast et al., 2019). An important question for future research is therefore whether and how co-benefits and their foundations are different in renewable-energy projects undertaken by firms from other countries. There is anecdotal evidence to inform research hypotheses here. Chen (2018) analysed the sustainable development measures, including economic benefits, of two wind farms (a Chinese-financed versus a French-financed wind farm) and found that no substantial differences could be identified in this respect. Similarly, other studies of renewable-energy projects in Africa driven by western EPCs and investors suggest that local economic benefits tend to be restricted, particularly in the infrastructure delivery phase (Gregersen, 2020). The conceptual framework developed in this paper, while devised to assess Chinese projects, is applicable more generally to research on the co-benefits of renewable-energy projects in Africa and may be useful in conducting further studies in this respect.

Lastly, we have emphasised that that reaping economic co-benefits depends significantly on the capabilities of local firms, specifically on the competence differential between foreign and local actors. Where this differential is too big, meaningful engagement and learning of local actors is difficult – unless prior training provided by foreign suppliers is written into the contract and monitored. Of key importance in this respect, as emphasised above, is the importance of initiatives for building local green infrastructure project-delivery capabilities, as opposed to the typical focus on technological capabilities related to the manufacturing of green technologies and on the service-delivery capabilities associated with their O&M. Little is known about how such project-execution capabilities are built locally, and future research should address this question. We contend that this is a crucial element in addressing the wider issue of how African host economies can maximise the benefits of green investments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices

Appendix A1: Explanatory variables

This appendix provides further information on the operationalisation of the key explanatory variables. Table A1 shows our framework for data collection and analysis and is a complement to the information provided in Section 2.2.

Appendix A2: Economic co-benefits

This appendix provides additional information and discussion about the co-benefits and related indicators presented in Table 2 of Section 2.3 and serves as the basis for interpreting the empirical findings presented in Section 4. It is important to note that there is a general lack of standardised indicators on the co-benefits of renewable energy projects on local economies.

In Fig. A2 below, we conceptualise the three different types of co-benefits achieved in each project as a continuum with theoretical minimum (or outright absence) and theoretical maximum (the

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 - Project developers - 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 - 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 - 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 - 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 - 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 - Medium - 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 - 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 - 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 - Decentralised

Authors' own elaboration.

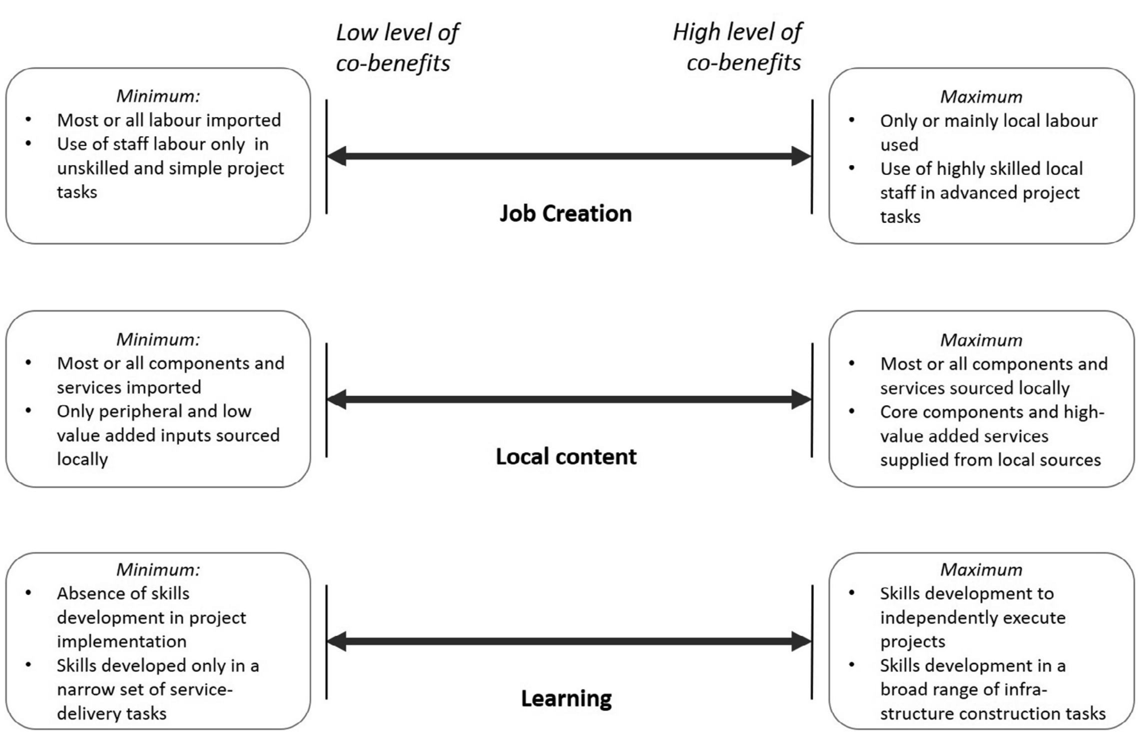

Fig. A1. Continua of project co-benefits. *Source*: Authors' own elaboration.

full potential) levels. We posit that a given renewable energy project can be placed at points (or intervals) along the continua. In the following, we discuss each of the three co-benefits and related indicators based on relevant literature.

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 extractives (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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