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BY
CECILIA THERESA TRISCHLER GREGERSEN

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JOURNAL ARTICLES

- Lema, R., Bhamidipati, P. L., Gregersen, C., Hansen, U. E., & Kirchherr, J. (2021). China's investments in renewable energy in Africa: Creating co-benefit s or just cashing-in? *World Development*, 141, 105365.*

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BOOK CHAPTERS

- Gregersen, C., & Gregersen, B. (2022). Interactive learning spaces: Insights from two wind power megaprojects. In R. Lema, M. H. Andersen, R. Hanlin & C. Nzila (Eds.) *Building Innovation Capabilities for Sustainable Industrialisation – Renewable Electrification in Developing Economies* (pp. 160-180). Routledge.*
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- Bhamidipati, P. L., Gregersen, C., Hansen, U. E., Kirchherr, J., & Lema, R. (2022) Chinese green energy projects in sub-Saharan Africa: Are there co-benefits? In R. Lema, M. H. Andersen, R. Hanlin & C. Nzila (Eds.) *Building Innovation Capabilities for Sustainable Industrialisation – Renewable Electrification in Developing Economies* (pp. 205-223) Routledge.

WORKING PAPERS

- Hanlin, R., Okemwa, J. & Gregersen, C. (2019) Building competences and capabilities through projects: examples from Kenya's renewable energy sector. IREK working paper http://irekproject.net

*Articles and book chapter that are included in this thesis

ENGLISH SUMMARY

In the light of urgent calls to action to tackle human-induced climate change and to achieve heavy reductions of carbon dioxide emissions, renewable energy technologies are widely promoted as part of the solution to regional, national, and local sustainable development. Many African governments are actively exploring how to combine energy access and climate change objectives with green energy investments. Ethiopia and Kenya are home to some of Africa's biggest wind energy projects. These projects have been highlighted as flagships of the renewable electrification process across the continent and they form the specific context for the research in this thesis. This thesis argues that renewable electrification is not simply about rolling out technologies, but also about transforming the relevant organisational and institutional settings and creating opportunities for co-benefits.

This thesis aims to contribute with new knowledge about localization of economic activities and development of local capabilities for designing, constructing, and supplying renewable electrification infrastructure such as windfarms. Learning and capability building are dynamic processes that are key to the development of local economic activities and for wind power projects to contribute to wider sustainable industrialisation. The overall research question guiding this thesis is thus:

- *How can large wind power projects contribute to build technological and organisational capabilities for sustainable industrialisation in Kenya and Ethiopia?*

The key findings are presented through four research articles using case studies from the Lake Turkana Wind Power project in Kenya and the Adama II project in Ethiopia. The first article provides an overview of the wind and solar markets in Kenya and compares the sectoral innovation system dynamics across size and shape of the projects. It brings together meso-level analysis of sub-sectoral dynamics with a discussion of the structural conditions and incentives that shape large wind power projects.

The second article looks deeper into the ownership of large renewable energy projects and explores the relationship between a specific Chinese model of investment and the extent to which economic co-benefits are created. The article opens for a discussion regarding the conditions and policy measures which may maximize the local co-benefits of renewable energy investments but also notes the complication of this because of power asymmetries in the negotiation of project conditions.

The third article focuses on the issue of local learning in the Lake Turkana Wind Power project and illustrates instances in which efforts to accumulate and build capabilities occur within and across different phases of the project as well as where

this is restricted. It elucidates the challenges of cumulative capability building and how potentially accumulated capabilities can be wasted without resources and a deliberate strategy to nurture them.

Finally, the fourth article examines different interactive learning spaces that arose or were created in the two wind power projects (Lake Turkana Wind Power project and Adama II) and policy contexts. The article gives concrete examples of how policy makers can outline and shape learning spaces which create distinctive types of interactions with the aim of capability building.

These findings suggest that it is crucial to explore the systemic and cumulative aspects and corresponding limitations and opportunities for technological and organizational capability building within and across phases of wind power projects. They also show that the ways in which wind power projects are organized and managed have important implications for how interactive learning can be created, shaped or be absent. The findings contribute to a better understanding of the importance of creating opportunities for learning, knowledge transfer, and co-benefits, emphasizing their deliberate design and active mangement. Yet they also emphasize that co-benefits are often of a restricted nature, that there is a lack of focus on learning and that there is therefore ground for caution against overly optimistic expectations of local learning from these projects. Importantly, the findings emphasize the systemic nature of learning and capability-building – and indicate that the more inclusive learning spaces can be, the wider the learning opportunities from projects.

This thesis contributes to the field of innovation and development studies by disentangling the interplay between capability building at the micro-level – within firms, within projects, across organizational boundaries and across phases of projects – and the meso-level dynamics shaped by structural conditions and incentives. By doing so, the thesis provides a comprehensive and scalable view on learning through renewable electrification. Overall, the thesis provides new insights into why, how and through which mechanisms learning and capability building opportunities arise in large wind power projects – this is important for bridging the gap between ambitions to couple renewable electrification efforts with economic development and sustainable industrialisation.

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DANSK RESUME

I lyset af de alarmerende krav om handling for at takle de menneskeskabte klimaforandringer og kraftigt reducere CO2 emissionen, bliver bæredygtige energiteknologier ofte fremhævet som en del af løsningen til at skabe en regional, national og lokal bæredygtig udvikling. Mange afrikanske regeringer undersøger aktivt, hvordan målene om øget adgang til energi kan kombineres med grønne energiinvesteringer. Etiopien og Kenya huser nogle af Afrikas største vindenergiprojekter. Disse har - på tværs af kontinentet - været fremhævet som flagskibe for en bæredygtig elektrificeringsproces, og de udgør den specifikke empiriske kontekst for denne afhandling. Afhandlingen argumenterer, at bæredygtig elektrificering ikke blot handler om udrulning af teknologier men også om nødvendigheden af at transformere den relevante organisatoriske og institutionelle baggrund og skabe muligheder for co-benefits.

Det overordnede formål med afhandlingen er at bidrage med ny viden om lokalisering af økonomiske aktiviteter og udvikling af lokale kapabiliteter til design, konstruktion og produktion af infrastruktur til bæredygtig elektrificering som vindmøllefarme. Læring og kapabilitetsopbygning er dynamiske processer, som er vigtige for udviklingen af lokale økonomiske aktiviteter og for at vindenergiprojekter kan bidrage til en bæredygtig industrialisering i bredere forstand. Det overordnede forskningsspørgsmål er således:

Hvordan kan store vindenergiprojekter bidrage til opbygning af teknologisk og organisatorisk kapabilitet til bæredygtig industrialisering i Kenya og Etiopien?.

Hovedresultaterne er præsenteret i fire forskningsartikler med casestudier af Lake Turkana Wind Pover projektet i Kenya og Adama II projektet i Etiopien. Den første artikel giver et overblik over vind- og solmarkederne i Kenya og analyserer dynamikker i det sektorielle system i et komparativt perspektiv på tværs af vind- og solprojekternes størrelse og form. Artiklen kombinerer mesoniveauanalyser af forskellige dynamikker inden for forskellige sub-sektorer med en diskussion af de strukturelle betingelser og incitamenter, som former store vindmølleprojekter.

Den anden artikel kigger nærmere på ejerforhold i store bæredygtige energiprojekter og undersøger forholdet mellem en særlig kinesisk investeringsmodel og i hvilken grad, der skabes økonomisk co-benefits med denne model som udgangspunkt. Artiklen åbner for en diskussion af hvilke betingelser og politikker, som vil kunne maksimere de lokale co-benefits knyttet til bæredygtige energiinvesteringer, men den peger samtidigt på de komplikationer, der er knyttet til en asymmetrisk magtfordeling ved forhandlingen af projektvilkårene.

Den tredje artikel fokuserer på elementer af lokal læring i Lake Turkana Wind Power projektet og illustrerer, hvordan det er muligt at opbygge og akkumulere kapabilitet inden for og på tværs af forskellige faser af projektet men også hvor mulighederne herfor er begrænsede. Artiklen belyser udfordringerne ved kumulativ kapabilitetsopbygning og hvordan potentielle akkumulerede kapabiliteter kan gå tabt på grund af mangel på ressourcer og en bevidst strategi til at stimulere en sådan opbygning.

Den fjerde og sidste artikel analyserer forskellige interaktive læringsfora (learning spaces), som opstod eller bevidst blev skabt i de to case-vindenergiprojekter (Lake Turkana Windpower projekt og Adama II). Artiklen giver konkrete eksempler på, hvordan politikaktører (policy makere) kan tilrettelægge og skabe læringsfora (learning spaces), som genererer distinkte interaktionstyper med det formål at opbygge lokal kapabilitet.

Resultaterne indikerer, at det er vigtigt at undersøge de systematiske og kumulative aspekter og korresponderende muligheder og begrænsninger for teknologisk og organisatorisk kapabilitetsopbygning, der findes og opstår indenfor og mellem vindenergiprojekternes forskellige faser. Resultaterne viser også, at den måde vindenergiprojekterne er organiseret og styret på, har afgørende betydning for hvordan interaktiv læring skabes og formes eller kan være fraværende på. Resultaterne bidrager til en dybere forståelse af vigtigheden af at skabe muligheder for læring, vidensoverførsel og co-benefits, med fokus på bevidst design og aktiv ledelse. Men resultaterne understreger også, at co-benefits ofte er af begrænset natur, at der mangler fokus på læring og at der er grobund for ikke at have for optimistiske forventninger til omfanget af lokal læring fra sådanne projekter. Resultaterne understreger den systemiske natur af læring og kapabilitetsopbygning og indikerer, at jo mere inkluderende læringsforaer kan blive, jo videre er læringsmulighederne fra projekterne.

Afhandlingen bidrager til feltet innovation og udviklingsstudier ved at udfolde det dynamiske samspil mellem kapabilitetsopbygning på mikroniveau – dvs. indenfor virksomheder, indenfor projekter, på tværs af organisatoriske grænser og på tværs af projektfaser – og strukturelle forhold og incitamenter på mesoniveau. Ved at gøre dette, giver afhandlingen et omfattende og skalerbart perspektiv på læring gennem bæredygtig elektrificering. Overordnet giver afhandlingen ny indsigt i hvorfor, hvordan og gennem hvilke mekanismer muligheder for læring og kapabilitetsopbygning opstår i store vindmølleprojekter – dette er vigtigt for at realisere ambitionerne om at koble bæredygtig elektrificering med økonomisk udvikling og bæredygtig industrialisering.

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This thesis is the result of a long journey with many supportive voices. Firstly, I would like to thank my colleagues in the IREK project for the joint experiences and discussions on the topic of renewable electrification. Thank you to Margrethe Holm Andersen and Rasmus Lema for bringing me on board this project and all the advice, guidance and support over the years. To my fellow PhD researchers Faith Wandera and Dominic Samoita I would like to say thank you for sharing this journey, and the experiences, frustrations and joys that have come along the way. Thanks to Ann Kingiri and Rebecca Hanlin for warmly welcoming me to ACTS during my stay in Nairobi. Thank you to Charles Nzila and Michael Korir for hosting us in Eldoret for my first IREK workshop. Thanks to Ulrich Elmer Hansen and Padmasai Lakshmi Bhamidipati for our collaboration on research papers. Very special thanks is owed to Nina Kotschenreuther and Jeanette Hvarregaard for the support that has come in so many forms from help finding actual things to navigating administrative and bureaucratic systems. Heartful thanks go to Abdi Yuya Ahmad and Addisu Bekele for taking such good care of me and facilitating my visit to Adama Science and Technology University (ASTU) and the Adama wind project. I would also like to express gratitude to all my research participants who generously shared their time and thoughts with me.

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Cecilia Theresa Trischler Gregersen, Copenhagen, July 2022

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CHAPTER 1. SYNOPSIS

1.1. INTRODUCTION

In the face of urgent calls to action to tackle human-induced climate change and to achieve heavy reductions of carbon dioxide (CO2) emissions, renewable energy technologies are widely promoted as part of the solution to regional, national, and local sustainable development. Many low and lower-middle income countries are actively exploring how to combine energy access objectives with green energy investments. According to the United Nations (UN, 2021) globally nearly nine out of ten people have access to electricity. However, out of the 789 million people with no access to electricity, 548 million people are living in sub-Saharan Africa. Thus, it will take an extra effort from a broad spectrum of actors to speed up the sustainable electrification process to secure access to affordable and clean energy for everybody in these areas.

On the one hand, forecasts show massive growth in investments in renewable energy infrastructure in Africa, and these energy infrastructure projects are both growing in size and maturity (Lema, Hanlin, Hansen & Nzila, 2018; Klagge & Nweke-Eze, 2020, Lema, Andersen, Hanlin & Nzila, 2022). On the other hand, it has been questioned (Hanlin, Andersen, Lema & Nzila, 2022) if access to clean energy will be sustainable in the long run when renewable energy supply mechanisms are mainly designed, constructed, operated, and maintained predominantly with foreign equipment, foreign financing, and foreign workers. A contribution to overcome this dilemma may be to put more emphasis on how to stimulate the development of local activities and capabilities in the deployment of renewable energy technology. In this way, synergies between energy-related and economic development strategies can be better exploited (Lema, Fu & Rabellotti, 2020; Hanlin et al., 2022; Andersen & Lema, 2022).

The renewable electrification process in fact holds the opportunity to create jobs in a range of areas from services to manufacturing and production. The experiences of countries like China and India show how renewables are becoming part of the industrialisation strategy itself and can set out a new path for sustainable industrialisation as a more holistic economic development strategy (Lema, Iizuka & Walz, 2015; Mathews & Tan, 2013). Attention to steering or guiding development pathways can provide solutions to problems such as expanding energy access while also spurring growth, jobs and resulting in positive spillovers, or co-benefits, across many sectors. The concept of co-benefits refers to the idea that renewable energy projects can create outcomes beyond the actual energy output, for example in terms of generating highly skilled service employment or production and manufacturing jobs (Andersen & Lema, 2022).

There is, however, a lack of evidence of the relationship between environmental policies and economic opportunities in low- and middle-income countries, as most research has focused on advanced industrialised countries (Pegels & Altenburg, 2020). Infrastructure investments are necessary and continuously take place and it makes sense to invest in state-of-the-art efficiency. However, building up capabilities for economic change, for renewable electrification, or innovation capabilities, constitutes an important missing link in ensuring the transition to a more sustainable development in developing economies (Hanlin et al., 2022). Specifically, there has been paid very little attention to the rising number of wind power projects in the sub-Saharan context in the academic world and the opportunities and limitations these developments have for wider sustainable industrialisation. It is within this gap that this thesis wishes to contribute by exploring and providing contextual knowledge of the role of capability building from wind power projects for sustainable industrialization.

In short, this thesis aims to contribute with new knowledge about localization of economic activities and development of local capabilities for designing, constructing, and supplying renewable electrification infrastructure such as wind power projects. As the remainder of this thesis will unfold, it does so specifically by operationalising learning and capability building as dynamic processes that are key to the development of local economic activities and for wind power projects to contribute to wider sustainable industrialization.

1.1.1. LEARNING AND INNOVATION CAPABILITIES FOR RENEWABLE ELECTRIFICATION

As outlined above, the transition towards more renewable-based energy systems is a major challenge that will require advances in the field of innovation and development research and our understanding of technological change and policy. Andersen and Lema (2022, p. 21) define renewable electrification as 'essentially equivalent to the production, deployment, and use of renewable energy' involving changes in both core technologies and the systems in which they are used. Renewable electrification includes both the creation of access to electricity to formerly non-electrified communities as well as transformation of existing energy systems with renewables such as solar and wind. Furthermore, it includes both large-scale, grid-connected deployment of renewable energy as well as small-scale, mini-grids and sometimes off-grid renewable energy solutions. Such transformation of the energy system will require a good understanding of the nature of technological change related to renewable energy technologies, including both theoretical conceptualizations and empirical evidence (Neij, Heiskanen & Strupeit, 2017). As argued by Lema, Iizuka & Walz (2015), it is not simply about rolling out technologies, but also about transforming the relevant socio-technical setting and creating opportunities for co-benefits. Many of the economic activities that may arise in connection with green energy investment projects are temporal in nature, but the benefits from learning opportunities that arise can have a more lasting effect on the change of economic development paths. In fact, from a learning economy perspective, learning is a fundamental feature of today's changing economy and therefore it is important to focus on the role of learning and knowledge (Johnson, 2011).

Experiences across a range of developing and newly industrialised countries have demonstrated that local technological capabilities and the knowledge to innovate on the transferred technology play an important role in enabling technology change and supporting development in a manner that is more locally rooted and more robust (de Coninck & Sagar, 2015). However, this has been underexplored because of its enormous complexity and context-dependence, but also because international climate policy approaches have focused largely on market mechanisms for the acquisition of technology across borders (Ockwell & Mallett, 2012). There is therefore a need for empirically grounded research that explores theories of technology and innovation capability accumulation explicitly within the context of low carbon energy technologies, and the contexts of sustainable industrialisation and development policy more broadly.

The main objective of the thesis is therefore to contribute to the understanding of, *why, how* and through *which* mechanisms technology and innovation capabilities can contribute to learning for sustainable industrialisation.

The overall objective will be explored more specifically in the context of renewable electrification in East Africa. Two notable renewable energy investments in the wind sector include some of Africa's biggest wind power projects - the Lake Turkana Wind Power project in Kenya and the Adama II project in Ethiopia. These projects exist in environments where energy systems are undergoing a transformation in terms of moving towards diversified renewable energy generation capacity while expanding electricity access. Several studies have examined the dynamics of the procurement programme and local content requirements in the South African wind energy sector (e.g., Rennkamp & Boyd, 2015; Furtado & Perrot, 2015; Baker & Sovacool, 2017; Morris, Robbins, Hansen & Nygard, 2021). However, there is a lack of studies documenting the emerging dynamics of wind energy deployment in other regions of the African continent, both in terms of the characteristics of projects, but also in terms of the wider technological and organisational capabilities surrounding them (Mukasa, Mutambatsere, Arvanitis & Triki (2015). Chen (2018) provided some insights into elements of knowledge and technology transfer in the Adama project in a comparative study with the Ashegoda project in Ethiopia. The Lake Turkana Wind Power project has been discussed in a review of the policy framework for wind in Kenya (Kazimierczuk, 2019) and has also been the focus of studies looking into the exclusionary effects of the construction of the project for local communities and the ensuing contentions (Cormack & Kurewa, 2018; Achiba, 2019). This thesis contributes to this emerging knowledge with a specific focus on the role of capability building and learning in these projects. By engaging in an in-depth study of opportunities and limitations for capability building from two of Africa's biggest wind power projects, this thesis provides important empirical evidence to support efforts towards sustainable industrialisation based on renewable electrification. The research presented in this thesis is thus guided by the following research question:

- *How can large wind power projects contribute to build technological and organisational capabilities for sustainable industrialisation in Kenya and Ethiopia?*

In order to respond to this question, the research brings together distinct perspectives related to economic co-benefits and capability building in renewable electrification processes in an integrated framework with different levels of analysis. This is done through both single-case studies and comparative case studies that are presented in four different research articles (see Chapters 2, 3, 4 and 5). The case studies comprise the Lake Turkana Wind Power project in Kenya and the Adama II wind power project in Ethiopia. The articles employ the concepts of co-benefits, technology transfer and collaboration, innovation systems and interactive learning spaces to illuminate issues regarding learning and capability building.

The remainder of the thesis is structured as follows: Section 1.2, describes the empirical context in which this research has taken place. Section 1.3 discusses the theoretical foundations to different analytical frameworks of learning, technology transfer and innovation systems. Section 1.4 outlines the methods used in this dissertation and the case study design. Section 1.5 summarizes the key findings of the four individual papers of this thesis. Section 1.6 discusses the findings of the papers considering the overarching research question and outlines the contributions to existing literature, avenues for future research and policy implications. Chapters 2, 3, 4 and 5 contain the four individual papers of this thesis as published.

1.2. THE EMPIRICAL CONTEXT: LARGE WIND POWER PROJECTS AND SUSTAINABLE INDUSTRIALISATION IN EAST AFRICA

Many African governments are actively exploring how to achieve their growth targets through a low carbon or even carbon neutral trajectory taking advantage of the large local renewable energy endowments such as solar, wind, geothermal, hydropower and biomass. The East African Community (EAC) states[1] are rich in renewable energy resources and the choices made by governments, policy makers, utilities, and power producers as well as users will define future energy systems. All EAC partner states have adopted electricity access targets with Kenya and Uganda's goals of 100% access to grid-connected power by 2030 being the most ambitious. Leapfrogging to 'smart' technologies is emphasised as allowing African countries to avoid costly lock-in of increasingly outdated technologies while addressing local and national energy service

[1] The EAC member states include the Democratic Republic of the Congo, the Republics of Burundi, Kenya, Rwanda, South Sudan, Uganda and the United Republic of Tanzania. Ethiopia is a member of other regional economic communities including the Common Market for Eastern and Southern Africa (COMESA) and the Intergovernmental Authority of Development (IGAD). Kenya is a member of all three regional economic communities.

requirements. The 2030 Agenda and the Sustainable Development Goals (SDGs), which have brought forward a particular focus on the role of renewable energy for global sustainable development, illustrate the ambitions for low carbon development globally.

As outlined above, attention must be paid to the synergies between energy, sustainable development, and industrialisation. There is broad agreement within both the policy and scholarly communities that if low-carbon and climate resilient technologies are prioritized globally, and if technology development and transfer policies are chosen carefully, developing countries will be better equipped to achieve their economic and social development goals in a more climate-resilient manner (Sokona, Mulugetta & Gujba, 2012; de Coninck & Sagar, 2015). For example, the African Agenda 2063 places a high priority on renewable energy in fostering economic growth and eradication of energy poverty (African Union & Commission, 2015). Also SDG 7 - to achieve universal access to affordable electricity by 2030 - emphasises that upgrading technology to provide clean energy in all developing countries is a crucial enabler of all three dimensions (social, economic and environmental) of the goals. SDG 9 - to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation - highlights renewable energy as an enabler and key factor for investments in infrastructure and innovation as drivers of economic growth and development. Focusing on sustainable industrialisation, according to UNIDO, can provide African countries a way of increasing employment, lowering energy costs, and reducing the pressure on infrastructure in cities as well as ensuring prosperity is shared across all those in society (UNIDO, 2020). However, to date, few African countries have managed to successfully integrate the high-value-added segments of renewable energy value chains and generate associated employment (IRENA & AfDB, 2022). It has been estimated that only around 323 000 people are employed in the renewable energy sector in Africa - less than 3% of renewables employment worldwide (more than 12 million people employed) (IRENA & ILO, 2021).

In scholarly communities, in particular in the cross-sections between innovation and development research, the need for indigenous capacities to enable the adaptation and improvement of imported technology has been emphasized (Freeman & Soete, 1997; Ockwell & Mallett, 2012; Urban & Nordensvärd, 2013; de Coninck & Sagar, 2015; Lema et al., 2018). Freeman and Soete (1997) argue that local research and development and adaptation of technologies is important not only on economic and technological grounds but even more so on cultural and political grounds. However, as Arocena & Sutz (2016) note, not every country needs to become a competitive producer of the new technology - instead countries should build their own capacity to use the building blocks of technologies and thereby increase their knowledge to solve problems. They argue that relying solely on knowledge import is a short-sighted view that does not adequately consider the learning effects of this type of decision. The role of industrial policy in stimulating economic transformation is increasingly recognized; however, the significant body of literature exploring the conditions under which industrial policy is successfully implemented has not typically included African cases or sought to explain African experiences (Whitfield & Buur, 2014). Given the importance ascribed to local capabilities for effective low carbon development, there is relatively little attention to ‘where’ and ‘how’ capabilities arise in local economies, and particularly there is little attention to the role of interactive learning as a means to building these innovation capabilities (Lema et al, 2018). Therefore, there is a need for more empirical work that explores the opportunities for capability building in relation to the investments being made in renewable electrification processes in Africa.

A critical issue for understanding how renewable energy deployment works, is that essentially it occurs as a ‘project’, and in the context of renewable electrification, renewable energy projects can be seen as ‘innovative projects’ (Davies & Brady, 2016; Hanlin & Okemwa, 2022). Innovative projects tend to be highly risky and unpredictable endeavours that are difficult to plan. They require novels ways of organising and a shift away from routine skills and capabilities. Furthermore, many wind power projects can be characterised as megaprojects - large-scale, complex ventures,that take many years to develop and build, involve multiple public and private stakeholders - and are often viewed as transformational (Flyvbjerg, 2017).

Globally, wind energy is one of the most commercialised and most successful types of renewable energy available. While wind energy has gained ground on the African continent, there is limited empirical work exploring and explaining the emerging dynamics of this sector (Mukasa et al., 2015). Kazimierczuk (2019) has suggested that international private participation in energy generation and renewable/wind energy expansion in Africa is critical and expected to increase. Countries in North Africa and South Africa are the frontrunners in terms of investments and installed capacity, but wind energy also features in energy expansion and growth plans in several other sub-Saharan countries, notably Kenya and Ethiopia in East Africa. At the end of 2020, wind generation capacity in Africa amounted to 6.5 Gigawatts, of which 0.7 Gigawatts were added in 2020. South Africa, Morocco, Egypt, Kenya, Ethiopia and Tunisia account for over 95% of Africa’s total wind generation capacity (IRENA & AfDB, 2022).

In East Africa, renewable energy accounts for around 80% of the electricity generation capacity, primarily through hydropower, but also through geothermal (all in Kenya), wind and solar power (IRENA & AfDB, 2022). Ethiopia and Kenya are the largest wind power producers in the region both with over 300 MW installed capacity. Kenya is home to Africa’s largest wind power project[2], the Lake Turkana Wind Power (LTWP) project, with a capacity of 310 MW. Ethiopia has three operational wind power projects with a combined capacity of 324 MW.

[2] In terms of MW installed in a single phase of a project

1.2.1. KENYA

The expansion of access to reliable and modern energy services, and rural electrification in Kenya has been a political priority since the turn of the millennium, where only 15 % of the population had access to electricity. Policies such as the Last Mile Connectivity Project, and sectoral reforms such as the creation of the Rural Electrification Authority (converted to Rural Electrification and Renewable Energy Corporation (REREC) in 2019) have successfully spurred a rapid increase in household connections from about 2.5 million in 2014 to 6.5 million in 2018 (Ogeya et al. 2022).

Successive reforms towards market liberalization, the unbundling of transmission and generation of power, the creation of new regulatory agencies as well as the focus on rural electrification characterize Kenya's current energy sector. The reforms have created space for private investment in and ownership of energy projects. Kenya Electricity Generating Company (KenGen) is a government owned company producing about 75% of electricity capacity installed in the country, mainly from hydro and geothermal sources. Independent Power Producers account for about 24% of the Kenya's installed capacity from a range of energy sources (Kazimierczuk, 2019). Kenyan Electric Transmission Company Limited (KETRACO) is responsible for the national transmission grid network.

The Kenyan government's long term development strategy 'Vision 2030', which was published in 2008, recognized energy as an important enabler for achieving its ambitious goals to transform the country into a 'globally competitive and prosperous, newly-industrialised, middle-income country with a high quality of life by 2030' (GoK, 2007). The strategy highlights the need to generate reliable, affordable and clean energy for the growing economy. Kenya subsequently pioneered feed-in-tariff (FiT) developments in the region to spur the development of solar, wind and small-scale hydropower.

Kenya's first wind power project developed from a pilot project in the Ngong Hills, initially installed in the early 90s, currently operated by KenGen at a capacity of 25.5 MW. The development of LTWP project can be traced back to 2006, before the FiT was developed. The LTWP project was approved by the cabinet as a flagship project for the Vision 2030. It took over 8 years of planning and development before construction of the project began in 2014. While the installation of the wind turbines was completed according to the planned timeline, the project experienced significant obstacles due to the delayed finalization of the transmission line to connect the project to the national grid. The LTWP plant became fully operational in 2018. Kenya's second largest wind farm, the 100 MW Kipeto wind farm was commissioned in 2021. Prospective wind power projects in Kenya have been limited to projects of 100MW or below. In 2021, Kenya had a total generation capacity of 435.5 MW from wind power.

1.2.2. ETHIOPIA

Ethiopia has historically focused largely on hydropower for electricity generation but has in recent years sought to diversify generation from other renewable sources as outlined in the Ethiopian National Development Plan - the Growth and Transformation Plan II (GTP II) (NPC, 2016).[3] This strategic document set out the Government of Ethiopia's (GoE) planned expansion of power generation capacity from 4,180 MW in 2014/15 to a mid-2020 target of 17,000 MW from renewable sources, of which wind energy will have a share of 5,200 MW. These ambitious targets have been set to contribute to the GoE's vision of achieving middle-income status by 2025 through building a green economy with carbon neutral growth. Several Ethiopian government entities, including the Ministry of Water, Irrigation and Electricity (MoWIE), Ethiopian Electric Power (EEP), Ethiopian Energy Authority (EEA), and Ethiopian Electric Utility (EEU), are responsible for these targets.

Over the past decades, the private sector has been acknowledged as a key player in the Ethiopian economy, however liberalization efforts have mostly meant reconfiguration of how sectors operate, and the state continues to play an essential role in the energy sector, with direct ownership of the entire electricity supply chain (Tesfamichael et al., 2021). Annual electricity demand in Ethiopia increased from 1.6 TWh in 2000 to 9.5 TWh in 2014/15. While 55% of the population live in areas covered by the national grid, less than 25% is connected to the grid (Danida, 2016). The GTP II plan also set an ambitious target to reach 7 million new customers by 2019/20. Therefore, substantial investment in the rehabilitation and expansion of the transmission and distribution network in areas covered by the grid are required.

Plans to develop Ethiopia's wind resources can be traced back to 2006 when several potential sites for wind farms were identified including Ashegoda, Adama, and Messebo-Harena. In 2008 the French company Vergnet were contracted to develop a 120 MW wind farm at the Ashegoda location. The project commenced in 2009 and was inaugurated in 2013. In 2009, HydroChina and CGCOC signed an EPC contract with EEP to develop a 51 MW wind farm in Adama. Construction of the Adama I wind power project began in 2011 and the plant was inaugurated in 2012. Subsequently, EEP signed another contract with HydroChina to add an additional 153 MW of capacity in the Adama II project. The Adama II project came online in 2015. The three projects amounted to a generation capacity of 324 MW from wind power in 2021. A phased project on the Ayisha site (120, 120 and 60 MW successively) is planned and under construction.

[3] Ethiopia's current strategic development is title 'Ethiopia 2030: The Pathway to Prosperity' and sets out a 10-year plan from 2021-2030. The GTP-II is outlined in this section as it was the guiding plan for the period during which the Adama II project was implemented.

1.3. THEORETICAL FOUNDATIONS AND ANALYTICAL APPROACHES

In the following sections, the theoretical context for the analysis of wind power projects is outlined. The key concepts and frameworks are presented. Throughout the section, there will be references to the individual research papers where more detailed elaborations of specific elements of the frameworks can be found. First, a brief introduction to the field of innovation and development, focusing on evolutionary perspectives of economics will be provided as a background for the theoretical and analytical approaches adopted in this thesis. The logic in which several analytical frameworks are combined in this synthesis will also be presented.

As mentioned above, this thesis positions itself within innovation and development research from an evolutionary economic perspective where technological change and innovation are seen to be results of an interactive process between various and diverse actors. As a research field, innovation and development advances the agenda on innovation and its relations to sustainable and inclusive development (Joseph et al., 2021; Lema, Kraemer-Mbula & Rakas, 2021). It has emerged from studies in the economics of technical change, and the role of science and technology in society and in the convergence and divergence among countries. Seminal works by Freeman (1974), Nelson & Winter (1982) and Lundvall (1992) build upon evolutionary approaches to economics stemming from Schumpeter and Marx, including their endeavors to assign a more central role to technical innovation, and the proposition of a larger, institutionally embedded evolutionary process not reducible to markets (Freeman & Loucã, 2001; Arocena & Sutz, 2016). As Freeman (1988) argued, it is the interaction between economics, science and technology, and institutions that is essential for understanding growth and development.[4]

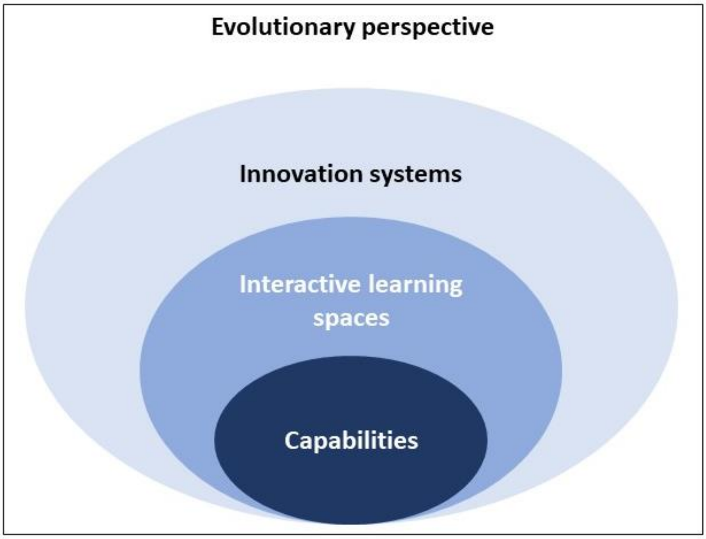
Both Freeman and Lundvall put the issue of learning at the center of their reflections around innovation and around convergence and divergence among countries. Freeman's inspiration on the central role of learning can be traced to List (1841; in

[4] Carlota Perez (2013) examines the question of whether innovation is only for the rich and outlines two traditional answers to this 1) the dependency school (Singer, 1949; Prebisch, 1951; Gunder Frank, 1967 and others) which held that Third World countries' futures were technologically dependent on the interests and decisions of foreign investors from the advanced world, and 2) the appropriate technology movement (e.g. Sen, 1960; Cooper 1972) which recommended the selection of technologies adapted to the endowments of the developing world, in the sense of being less capital-intensive and using more labour. However, both answers assume technical change to be continuous and cumulative and that technology came from the North and that countries in the South had to choose the most appropriate. Perez (2013) argues that today we rather see dynamic innovation systems, policies for enabling innovation and catch-up, upgrading of local companies and new pathways for development in developing countries. This is because technical change is constant but also discontinuous.

Freeman 1995) who argued that the state of nations is the result of the accumulation of all discoveries, inventions, improvements, perfections and exertions of all previous generations and that making use of and increasing those attainments is how nations can be 'productive'. This characterization of learning as a process of building upon, or accumulating, and putting into use different capacities to carry out productive tasks is similar to the definition of learning and capability building which will be explained further and employed in this thesis. In acquiring and adapting capabilities over a period of time, individuals, organisations or nations (depending on the level of analysis) are engaging in a process of learning. Furthermore, learning is seen to be embedded in complex, evolving systems which demonstrate co-evolutionary dynamics and emergent properties (Loucã, 2020).

Against this backdrop, Figure 1-2 below presents the overarching theories and concepts used and the logic for how they are presented and related in this thesis.

Figure 1-1 A nested analytical framework



The analysis of learning presented in this thesis treats capabilities as the basic building blocks of learning. However, there is a dynamic relationship between learning and capability building where learning can be seen as both the outcome of capability building as well an important element of the accumulation of further or different capabilities. While there are numerous ways to categorize and distinguish different types of capabilities (e.g., Lall, 1992), this thesis focuses on the distinction between technological and organizational capabilities. This distinction is used to acknowledge the sector specificity of wind power technologies, but also to allow space to examine broader organizational dynamics not necessarily solely related to the technological choice of these projects. Capabilities have been studied at both firm, sector and national levels, for example by function (e.g., investment and production capabilities and a range of sub-sets of these) and by degree of complexity (e.g., from simple, routine capabilities to innovative and risky capabilities). These building blocks (capabilities) can be distinguished in different ways and can also be contextually embedded at different (nested) levels of analysis. This thesis uses the frameworks of innovation systems and interactive learning spaces to illustrate the importance of context and the wide range of determinants that will influence the actors and their relationships involved in the process of building capabilities. It must be noted that in this thesis, interactive learning spaces are seen to be sub-elements of innovation systems. However, the frameworks have been used in separate analyses and are thus inter-related but can be used and understood distinctly. The overarching idea of technology transfer relates to interactions between actors both within and across these levels of analysis and will be explained from an evolutionary perspective in the following section.

The following elaborates each of the four levels in Figure 1-1 starting with the implication of an evolutionary perspective.

1.3.1. AN EVOLUTIONARY ECONOMIC PERSPECTIVE OF INNOVATION, TECHNOLOGY, AND ITS TRANSFER

This thesis identified technology transfer literature as an early starting point in examining learning and capability building that can arise from the implementation of wind power projects as part of renewable electrification strategies. The basic idea of technology transfer builds upon the notion that cross-border flows of technologies (from one firm to another, or from one country to another), as for example the transfer of wind power technologies, are essential to the process of economic growth and to the process of 'catch up' (Lema, Fu & Rabellotti, 2020). However, the theoretical understanding of technology and technological change in technology transfer literature varies substantially and will be introduced here to explain the approach taken in this thesis (Radosevic, 1999).

In classical and neoclassical economics, mastering technologies was assumed to be an almost automatic by-product of high investment rates - a given that was easily available, reproducible, and transferable (see for example Arrow, 1962 or Solow 1956). Technology in this tradition is assumed to consist of a set of techniques wholly described by their blueprint, taking two main forms: codified information (or disembodied technology), and capital goods (embodied technology). From this point of view, technology becomes generic and easily transferrable among organizations and locations. Furthermore, there is little need for industrialising countries to develop their own resources for generating and managing technical change when they have access to the existing global technology pool. Underlying this theory, Bell & Pavitt (1995) note that there are several contingent assumptions, such as

i) the ability to draw a sharp distinction between technological innovation and the subsequent diffusion of technology,
ii) the corresponding distinction between the sectors of the economy producing innovative technology and those using it
iii) that industrial technologies tend to be transferred to developing countries at late stages in the product or technology cycle
iv) that provided that workers have been sufficiently trained in basic operating skills, efficiency can be improved through the accumulation of production experience or 'learning by doing', and finally,
v) that technological change occurs only intermittently, and efficiency tends to move forward in distinct 'steps' as a result of innovation in industrial countries.

These types of growth models, however, have been criticised for ignoring the possible problems of technology transfer stemming from the idiosyncratic and localised nature of technology (Radosevic, 1999). In contrast, neo-Schumpeterian or evolutionary economists argue that technology is much more complex and can only partially be encompassed by either codified or physical capital (Bell & Pavitt, 1995). Both the operation of existing technologies and innovation require tacit knowledge that is highly specific to particular products, processes, firms and markets and can therefore only be acquired through trial and error and the accumulation of experience in particular contexts. Furthermore, evolutionary economics is very much focused on the notion of systems as opposed to linear models. Technology variation, selection and retention is the result of in a basic sense a collective process, where technological trajectories emerge in certain context conditions and through a cumulative process that builds on other people's advances. Yet the pathways are not necessarily inevitable and deterministic, but can be shaped by groups of individual firms that lead the system in one way or another (Nelson & Teece, 2010)

It is important to note that in evolutionary economics technology is viewed as more than the physical equipment or 'hardware' alone. Operating technologies involves complex relationships between equipment, process characteristics, product specification and work organisation, i.e., a fair share of 'software'. From this perspective, technology is viewed as firm-specific knowledge, and part of an individual firm's intangibles, revealing the possible limits to the transferability of technology. Firms that have created and moulded specific configurations of technological hardware and software, must be able to continually remould this bundle for the firm to remain competitive. The technological capabilities required for 'catch up' in this perspective must therefore include the capacity to generate and manage the continuous as well as discontinuous changes.

An evolutionary perspective also emphasises that most technological efforts do not take place at the frontier of technology but are rather focused on making explicit the many tacit elements of technology, and to access, implement, absorb, and build upon the knowledge required in undertaking production. The process is cumulative and while it includes both gradual technical change and discrete leaps in technical opportunities, even the most conspicuous single innovation has its roots in accumulated knowledge and experience (Lundvall, 2016). For example, Lundvall (2016) argues that the interaction between users and producers exchanging product information and innovation is a process with a big impact on organisations and that it can influence the rate and direction of technical change.

In addition, many of the improvements that can be identified are localised and specific to firms, products, and markets, because acquired technology is adapted and improved on both during initial investments as well as in their operational lifetime. While the providers of technology may be able to contribute to localised processes of technical change, key to this process is rather the domestic development of capabilities in recipient firms or countries. This has also been labelled as an issue of ‘learning from importing’ of products and services (Hanlin et al., 2022). Bell & Pavitt (1995) have also emphasized the need to accumulate capabilities through deliberate investment in specialised resources (such as a highly skilled labour force) to ensure a continuous learning and innovation process. Again, an evolutionary economics perspective emphasises that efficiency improvements in production do not follow automatically from the acquisition of foreign machinery and related operating know how. Furthermore, ‘learning by doing’ alone will not keep the technology importing firms competitive. The localised and continuous nature of technical change means that competitiveness is not simply a finite level that can be reached. Rather it is a constantly changing state and accumulating the capabilities to generate these changes is key for remaining competitive. Finally, an evolutionary perspective highlights the interactive nature of technical change, as both the producers and users of technology can generate change.

Summing up, an evolutionary perspective of technological change implies that innovation and technology transfer are results of interactive processes between varied and diverse actors, networks, continuous learning processes and conducive institutions such as policy incentives and trust (Pugh & Chiarini, 2018). This approach is fundamental to the overall framework for this thesis and is explained in further detail using empirical case studies in Papers 3 and 4 of this thesis. This thesis draws on the evolutionary perspective of technology transfer, in particular subscribing to considerations regarding the nature of innovation, its diffusion, and the accumulation of technological capabilities in developing or industrialising countries. Paper 3, provides a more detailed explanation of an evolutionary approach to technology transfer, examining different flows of technology, ranging from hardware to software, and unpacks a non-linear view of technology transfer among a complex network of actors. Paper 4 examines how two different wind power projects offer different examples of transfer of technology, involving both formalised and tacit knowledge transfer. The paper emphasises how interactive learning spaces which foster different kinds of learning and knowledge transfer can be created, exist, or cease to exist based on actions and strategies of different stakeholders involved in projects. The article thereby takes a contextualised view of how different actions of firms influence learning about wind power technologies. Similarly, Paper 2 distinguishes between three main units of analysis, including 1) the flows of capital and technology, 2) the local institutional and economic conditions and 3) the nature and organisation of the investment project. These factors reflect the idea of technology transfer as an embedded process where system dynamics at both project level and the wider economic conditions will influence the process.

The following section will sum up the idea of innovation systems, which brings together many of the fundamental theoretical concepts outlined above in a systems perspective.

1.3.2. INNOVATION SYSTEMS

The notion of innovation system refers to the assumption in evolutionary economics that technical artefacts or innovation do not operate in isolation. Rather, their functioning is highly dependent on specific and complex ensembles of elements in which they are embedded (Borrás & Edler, 2014).

The study of innovation systems emerged as framework for understanding differences of economic development and various ways to support technological change and innovation (Chaminade, Lundvall & Haneef, 2018). The approach developed in the 1980s in a discussion among scholars including Freeman (1987), Lundvall (1992) and Nelson (1993). These initial works on innovation systems were focused on the national level, but inspired work on regional (Asheim & Gertler, 2004) or local levels, sectoral systems (Malerba, 2002, 2004) as well as technological systems (Carlsson & Stankiewitz, 1995). Whichever level of analysis is chosen, there is importance attached to the socio-economic context shaping the capability of organisations, regions or countries to develop, diffuse and use innovation. This thesis specifically adopts the sectoral level of analysis in Paper 1, but the following will introduce innovation systems more broadly, before presenting the main tenets of the sectoral perspective.

As mentioned above, innovation systems literature emphasizes that innovation is an interactive process where different kinds of knowledge are combined through communication within and across organisational borders. Firms absorb ideas from users, suppliers, knowledge institutions and the innovation process involves interaction with many kinds of actors (Kline & Rosenberg, 1986; Lundvall, 1985; Chaminade, Lundvall & Haneef, 2018). The meso- and macro-economic contexts in which firms operate, including the institutions and organisations that systematically interact, influence the rate and direction of technological change in an economic system (Lundvall, 1992; Nelson, 1993). While the innovation systems approach can have varying definitions of systems, across all levels it involves the creation, diffusion, and use of knowledge (Carlsson et al. 2002).

The innovation systems perspective is in a sense an interdisciplinary approach, as it includes not only the economic factors influencing innovation, but also the institutional, organisational, social, and political factors, an approach that Edquist (1997) noted as political-economic. However, definitions of systems vary from more narrowly selected institutions, to broader and encompassing definitions that include many parts of economic structure. For example, Freeman (1987, p. 1) defined a system of innovation as ‘the network of institutions in the public and private sector whose activities and interactions initiate, import, modify and diffuse new technologies’. Lundvall (1992) employed a broader sense of the concept including all parts and aspects of the economic structure and the institutional set up affecting learning as well as searching and exploring, arguing that any definition of a system must be kept open and flexible regarding which sub-systems and processes should be studied. Edquist provides an even broader definition, “all important economic, social, political organizational, institutional and other factors that influence the development, diffusion and use of innovations” (Edquist, 1997, p. 14).

Lundvall’s (1992) contribution focuses on the theoretical roots of the innovation systems approach, stressing the process of learning and user-producer interaction. The systems of innovation approach is thereby compatible with the notion that processes of innovation are, to a large extent, characterised by interactive learning. Edquist (1997) suggests that some kind of systems of innovation approach is inherent to any perspective that sees the process of innovation as interactive; interactivity paves the way for a systemic approach. As noted by Lundvall, a theoretical core of innovation studies is based around a perspective in which innovation is seen as an interactive process (Lundvall, 2013).

As mentioned above, a large part of the early work on systems of innovation was focused on the national level due to the different case studies that showed sharp differences between various national systems in attributes such as institutional set up, investment in R&D and performance. But several other innovation systems scholars have focused on different levels of analysis. Economic geographers have focused on innovation as an interactive process located in geographical space and use the concept of regional innovation systems (Asheim & Isaksen, 1997). Carlsson and Stankiewicz (1991) introduced the concept of technological innovation system, focusing on the interaction between organisations and how this evolves over time as new technological systems emerge, develop, and become settled. Breschi and Malerba (1997) used the concept of sectoral systems of innovation to understand industrial dynamics.

It must be noted that a large part of the studies applying the technological innovation systems (TIS) have focused on studying the emergence of clean tech sectors and has become a major block of sustainability transitions research (Bergek et al., 2015). This specific variant of innovation systems focuses on understanding how the system around a particular technology functions, e.g., small wind turbines in Kenya (Wandera, 2021), solar PV in Ethiopia (Kebede & Mitsufuji, 2016) or the emergence of wind energy industries in Brazil and South Africa (Furtado & Perrot, 2015). Bergek et al. (2008) define the TIS as the socio-technical system focused on the development, diffusion, and use of a particular technology in terms of knowledge, product, or both. A technological innovation system may be a sub-system of a sectoral system or may even cut across several sectors and they are often international in nature, i.e., not limited to e.g., a national context.

The sectoral perspective has rather focused on understanding what is specific about each sector and technology. Malerba (2002, p. 250) defines a sectoral innovation system as ‘a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products.’ Sectors change over time, and therefore a lot of attention should be placed on their dynamics, emergence, and transformation. They are characterised by specific knowledge bases, technologies, production processes, complementarities, demand, by a population of heterogenous firms and non-firm organisations and by institutions. The elements within each sector are closely connected and their change over time results in a co-evolutionary process of the various elements. In paper 1, this thesis draws on the sectoral system of innovation to examine the dynamics of two renewable energy sectors in Kenya – solar and wind. In examining differences in terms of size of projects and choice of technology, the sectoral innovation systems can help to highlight sector-specific characteristics of industrial evolution. The paper also argues for the need for a further disaggregated analysis (sub-sectors) and highlights the co-existence of different innovation systems within broadly defined sectors. Papers 2, 3 and 4 do not explicitly use innovation systems frameworks but across all papers the notion of interaction among actors in variously defined systems is central to the analysis.

The following section will introduce the concept of interactive learning spaces which can help to understand some of the relations between actors in innovation systems.

1.3.3. INTERACTIVE LEARNING SPACES

As indicated above, the school of evolutionary economics has enhanced our understanding of innovation as an interactive process and our understanding has moved from a linear model, to a more systemic one, with an underlying conception of innovation as complex, interactive, and evolutionary (Pugh & Chiarini, 2018).

This section briefly dwells on the concept of interactive learning spaces, defined as “situations in which different actors are able to strengthen their capacities to learn while interacting in the search for the solution to a given problem” (Arocena & Sutz

2000, p. 1). The concept of interactive learning spaces integrates the coexistence of learning capabilities and learning opportunities in a specific context.

An interactive learning space is a social space created as opportunities for knowledge producers and users to build innovation capacity, and to devise solutions to specific social and economic problems through interaction. “Relevant learning processes related with problem solving include the capacity to recognise the useful existing knowledge, to detect the missing knowledge needed, to organise the search process to acquire it, to integrate new knowledge into the previous base and the whole into current practices.” (Arocena & Sutz 2000, p. 7).

The concept thus relates to the idea of absorptive capacity, which is defined as “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends.” (Cohen & Levinthal, 1990, p.128). The interactive learning space concept can be seen as a framework to focus on when and under what institutional settings absorptive capacity may develop and how it can be supported by a deliberate process. The institutional settings within and around the projects, and the ability to shape these to foster capability accumulation, are key in shaping the path from technology adoption to learning and innovation (Lema, Iizuka & Walz, 2015).

However, interactive learning spaces can both occur as a reactive, problem-solving process or as the result of a proactive and deliberate strategy (Johnson & Lundvall, 1994; Johnson & Andersen, 2012; Petersen et al, 2018). In practice, the two forms can interact and mutate into new mixed forms, and it is relevant to identify and study them empirically – how they emerge, grow and disappear - as is done in Paper 4. As noted by Arocena & Sutz (2000) interactive learning spaces can be seen as embryonic points in the development of innovation systems. While Paper 3 provides an overview of actors and opportunities for learning across the 1) planning phase, 2) construction phase, and 3) operations phase of a wind power project, Paper 4 focuses on particular ‘learning spaces’ which arise in different wind power projects and examines distinct 1) learning focused on project management related to project development and construction and 2) learning focused on operations and maintenance. The distinction between multiple learning spaces indicates the multiple sets of capabilities required in complex projects. Across all the research papers in this thesis, the different actors and relations are outlined, illuminating the multiplicity of learning and capability pathways that may arise.

The next sections will provide more details about the capabilities perspective and outline some issues regarding specificity of context for the accumulation of technological and innovation capabilities in the wind sector. As Bell & Pavitt (1995) point out, interactions and the process of accumulation of technological capabilities is highly dependent on the type of industry in question.

1.3.4. TECHNOLOGY TRANSFER AND CAPABILITY BUILDING

From the above discussions, it is clear that the transfer of technologies necessarily requires learning and that users of technologies have the ability to influence the direction of technical change. However, a user or receiver of the technology will also need to use existing skills and knowledge bases as well as significant investments to 'master' the technology. For clarity, it is important here to dwell on the concepts of capabilities and learning. The following explanations will draw on Dosi, Nelson & Winter (2000) who explain from an evolutionary economic perspective how capabilities are used to justify how firms and other organisations 'know how to do things'- e.g., like building a wind energy power plant. What does this mean? How do organisations know how to do things? The proposition that firms and organisations can 'know' how to do something assumes organisational knowledge as a real thing that is acquired, maintained, extended, and sometimes lost. Particular forms of organisational knowledge can account for an organisation's ability to perform and extend its characteristic 'output' actions – e.g., the creation of a product, provision of a service or development of new products and services. Organisational capabilities can thereby be defined as the know how that enables organisations to perform these sorts of activities.

Dosi, Nelson & Winter (2000) emphasize the role of intentionality when it comes to building capabilities. They argue that to be capable of some thing is to have a generally reliable capacity to bring that thing about as a result of intended action (Dosi, Nelson & Winter (2000, p.2) – capabilities fill the gap between intention and outcome. They thus distinguish 'capability' from 'organisational routines', as routines have no presumption of deliberation of choice, whereas capabilities are significantly shaped by conscious decision both in development and deployment. In acquiring and adapting their capabilities over a period of time, organisations are doing something that can reasonably be called organisational learning. Or put differently, learning is the effort to improve capabilities.

A large body of literature on capabilities has also emerged from the field of strategic management which focuses on how organisations will tend to specialise in activities for which their capabilities offer some comparative advantage (Richardson, 1972; Teece, 2017). Importantly, in this view, capabilities are untethered from specific products and arise in part from learning, from combining resources and from leveraging complementary assets. Teece et al. (1997) distinguish between ordinary capabilities and dynamic capabilities - ordinary capabilities are to a large extent operational (doing things right), whereas dynamic capabilities are generally strategic in nature (doing the right things). The concept of dynamic capabilities points in the direction of broadly being concerned with the firm's ability to carry off the balancing act between continuity and change in its capabilities, and to do so in a competitively effective manner.

Another field of study with a focus on capabilities stems from research that examines the way organizations deal, or fail to deal, with technological challenges, and that has studied the patterns of change in knowledge bases underlying innovative activities and the related dynamics of 'technological paradigms' (Dosi, Nelson & Winter, 2000). The impact of new technologies and how these can change the way in which central functions of industries are performed has been the focus of research on industrial dynamics. This perspective on capabilities investigates how different firms react to the challenge, distinguishing between leading firms or incumbents and pioneers of new technologies, exploring how they adjust capabilities to cope. This has led to research into the directions of capability accumulation. Similarly, a capabilities view sees aggregate economic progress largely as the consequence of a multiplicity of actions at the firm level. From this perspective an improved understanding of the dynamics of capabilities at the level of individual organisations provides the foundation for an improved and qualitatively different understanding of the mechanisms of aggregate economic growth. Across all these fields where capabilities are important elements of analysis, the aim is to understand capabilities, technological or organisational, of heterogenous firms, nested in the competitive dynamics of industries and economies.

Based on work by Lall (1992) technology transfer frameworks often distinguish between production capacity and technological capabilities. Production capacity is defined as encompassing the resources used to use a technology at given levels of efficiency and input combinations. Technological capabilities are defined as the skills, knowledge and experience that differ substantially from those needed to operate existing technical systems. Importantly, technological capabilities also incorporate the kinds of institutional structures and linkages necessary to learn, absorb and provide inputs for technical change.[5]

For industrialising economies, the production capacity and technological capabilities are not necessarily closely nor effectively linked. This is due to the historical change in the way industries have evolved, where increasing specialisation has widened the gap between the kinds of knowledge and skills required to use given technologies and those required to create and change technology. Skills based only on cumulative operational experience have become progressively inadequate as a basis for generating change (Bell & Pavitt, 1995). The trend towards increasing organisational differentiation has also reinforced this differentiation.

In the case of wind power projects, it is useful to analytically distinguish between three sets of chains with distinct but related sets of capabilities - a production chain, a

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[5] Bell and Albu (1999) centre on the distinction between production systems and knowledge systems. They argue that since technological change is essentially a knowledge-centred process, it is important to map the knowledge stocks and flows and processes to understand the varying technological dynamism of industrial clusters.

deployment chain, and a user chain (Andersen & Lema, 2022). The production chain focuses on the production of core technologies such as wind turbines, and includes product engineering and design, component manufacturing and equipment and assembly. The deployment chain focuses on how such key technologies are put to use in specific contexts and countries and includes planning, finance, construction, connection, operation, maintenance, distribution, and consumption. Finally, the user chain related to distribution and consumption of energy – and the technologies used to secure this, e.g., national electricity grids. In each step of these chains, there are multiple actors involved - from foreign technology suppliers involved in the production of core technologies, to regional or local companies importing core technologies, or, assisting in assembling systems near local markets to companies engaged in transporting elements to project sites, preparing the project site, and connecting the energy producing system to national grids. The interactions between different actors in the steps of the value chains differ and may provide more or less efficient and effective possibilities for learning and building different types of capabilities.

While most technology transfer studies have focused on sector-wide capability accumulation to increase production and manufacturing, this thesis focuses on the deployment chain for wind energy projects, and papers 3 and 4 make further distinctions across different functions or phases of wind power projects. Projects such as wind power plants involve large networks of relationships between many firms, each with segmented streams of work packages and different types of relationships offer different opportunities for learning and capability accumulation. Furthermore, different projects show variations in their set-up, partners engaged and the energy systems in which they are embedded.

In this thesis, a distinction between technological and organisational capabilities has been adopted. As outlined above, organisational capabilities refer more broadly to the know-how of organisations to perform their characteristic outputs, whereas technological capabilities refer more specifically to firms' skills, knowledge and experience that can provide input to technical change. This distinction is important to understand the different 'functions' of different actors involved in projects. Furthermore, as outlined above, the wind power deployment chain involves many functions or activities that are not directly related to the core wind power technologies but involve organisational capabilities that are related. For example, Paper 4 makes the distinction between capability building in maintenance of the wind power technologies and in overall project management.

1.3.5. SUMMARY

The levels of analysis vary in each paper, from Paper 1 with a sectoral level of focus, to Papers 3 and 4 with a project level focus. Paper 2 combines the global level focus with primarily Chinese finance and production actors and looks at their impact on the project level in three different countries. Table 1-1 below provides an overview of the key concepts as they are used in this thesis. In the various papers, these definitions are discussed further.

As such, this thesis is made up of a combination of different types of innovation system theory and project-based approaches with foundations in literature about technology transfer and capability building. A common point in these theoretical frameworks is that learning and technology transfer or diffusion is understood as an interactive rather than a linear process. Innovation system research has long acknowledged the importance of the socio-economic context shaping the capability of organisations, regions or countries to develop, diffuse and use innovations. This indicates a fundamental assumption in this thesis – that innovation is embedded in specific social, political and economic relationships and it is largely influenced by the particular institutional context in which these relationships take place (Cozzens & Kaplinsky, 2009).

Summing up, this section has outlined the key features of the evolutionary perspective on innovation and technological change which present the theoretical foundations across the concepts and theories used in each paper are (see also Table 1-1). The overall characteristic that provides a red thread through the different concepts is the predisposition towards a more holistic and interdisciplinary approach. There is also an understanding of the historical and evolutionary perspectives, with directionality, the importance of accumulation and the importance of shaping forward pathways being of key importance. Finally, the approach fundamentally rests upon issues of interdependency between agents in systems and non-linearity of flows of knowledge and technology.

Of key significance are the delimitations when using frameworks such as the innovation systems approaches and the importance of specifying what should be included or excluded from the system and where the system boundaries are. As noted above, the different levels of analysis can be viewed in a nested manner, and as such can be combined. There is an inherent interplay between different levels of systems and some flexibility must be used in the choice of the unit of analysis, the variables examined and the fine-grained analysis that must be conducted. Sometimes the analysis must be broader, sometimes narrower. These levels of analysis all draw on evolutionary economics and help illuminate the key questions from different degrees of aggregation. In the research articles of this thesis, a range of different levels of analysis have been outlined across various systems from the global to the local and thereby setting limits for the analysis in various cases. This thesis thereby contributes by bringing together and integrating different levels of analysis for a comprehensive and scalable view on learning for renewable electrification and wider sustainable industrialisation.

Table 1-1 Key theoretical concepts and definitions

Key theoretical concept	Definition of key concept as used in this thesis	Developed in paper
Capabilities	Having the capacity (resources, skills/competences, and knowledge) to carry out a task (Andersen & Lema, 2022, p.35)	Papers 3 & 4
Learning	The accumulation of relevant capabilities (Andersen & Lema, 2022, p. 32)	Papers 3 & 4
Sectoral innovation system	A set of products for specific uses and the set of agents interacting for the creation, production and sale of those products (based on Malerba, 2002)	Paper 1
Co-benefits	Additional benefits that can potentially accompany the green-energy transition (local content, jobs, and technological learning) (based on Hansen et al. 2021)	Paper 2
Technology transfer	The dynamic movement of technology from one place to another (based on Gregersen, 2022)	Paper 3
Interactive learning spaces	Situations in which different actors are able to strengthen their capacities to learn while interacting in the search for the solution to a given problem (Arocena & Sutz, 2000, p. 7)	Paper 4

1.4. METHODOLOGY

This thesis engages with a broad set of analytical approaches and theories by zooming in and out of different units of analysis. This approach has required use of different methods. In this section, the methodological implications of such an approach are discussed. The section includes a presentation of the overarching research approach, the case study research design, and the methods for data collection and analysis.

1.4.1. RESEARCH APPROACH

This PhD project was conducted in a research setting characterized by the Innovation and Renewable Electrification in Kenya (IREK) project, with an emphasis on societal relevance, interdisciplinarity, and collaboration with societal actors. The underlying approach of the thesis is based on a pragmatic research philosophy, which emphasizes that the process of inquiry is a social phenomenon.[6] The focus is on the relation between knowledge and action and knowledge accumulation – knowledge is truthful to the extent that it is successful in guiding action (Bechara & Van de Ven, 2007). While there are many strands of pragmatism, this thesis subscribes to a pragmatic realist stance, i.e., with an objective ontology, or the belief that there exists a reality independent of cognition. However, pragmatism emphasizes that reality is a dynamic, constantly changing phenomenon on its way to becoming constituted but never quite 'finalised' (Kelemen & Rumens, 2008). This requires focus on the process and is usually coupled with a relational perspective on social concepts – in particular, focusing on the interrelationships between social entities – fraught with indeterminacy, ambiguity, difficult to predict, know or control at a distance. This approach suits well to the theoretical concepts used throughout the articles, in particular the systems perspective, where organisations and actors are seen as part of a web of interconnecting, heterogenous actions. For a pragmatist approach, this relational and processual dynamism is ubiquitous and central to social life.

Abduction is seen by some as the essence of pragmatism, i.e., seeking to reconcile that knowing and doing are indivisibly part of the same process (Campbell, 2011). It involves systematically moving back and forth between modes of induction and deduction, or a mode of reflexive inquiry that starts with a working hypothesis, which is then revisited and revised in light of new evidence (Rumens & Kelemen, 2008). Rescher (2003) maintains that the aim of science is to provide useful models of reality, and while we can never fully understand the complexity of that reality our knowledge about it is fallible. Hence going back and forth between theory, analysis and data lets us understand the value of theory and concepts in their use. This thesis progressed in an abductive mode of analysis, where data has been collected and analyzed from

[6] Pragmatism emerged as an American philosophical school of thought in the late nineteenth century and central figures include Charles Peirce (1839-1914), William James (1842-1910) and John Dewey (1859-1952).

various theoretical perspectives, a process in which the contributions and limitations that each can provide were unfolded.

The starting point of the research was a practical one, framed by the IREK project. The focus on large wind power projects was part of the PhD requirements and from there, the thesis evolved to combine technology transfer, innovation systems and other theoretical frameworks, with an overarching theme of learning and capability building. While the above describes the methodology for thesis, i.e., the theory of knowledge and the interpretative framework that guides the research project, the following sections will describe the methods, or techniques for gathering empirical evidence, starting with the case study research design.

1.4.2. CASE STUDIES

In order to capture as dynamic a picture as possible of large wind power projects, an in-depth and case study methodology is chosen. The thesis thus draws upon historical and in-depth empirical evidence from two major wind farm projects in Kenya and Ethiopia. This suits the context-dependent framing of the research problem and research (Flyvbjerg, 2006).

The case study method provides the opportunity to explore and describe a phenomenon in context using a variety of data sources. Case research can be defined as “a research method that involves investigating one or a small number of social entities or situations about which data are collected using multiple sources of data and developing a holistic description through an iterative research process” (Easton, 2010, p. 119). Conducting a case study involves both the deconstruction and reconstruction of the phenomena in question. In this case, the phenomena of learning and capability building can thereby be explored through a variety of lenses allowing for multiple facets of the phenomenon to be revealed and understood.

A strength of case study design is the ability to deal with a variety of empirical evidence, from documents and interviews to observations (Yin, 1994). As an empirical method, case studies investigate a contemporary phenomenon in depth and within its real-world context. It is especially useful when the boundaries between phenomenon and context may not be clearly evident. This perspective on case studies is based on a realist ontological stance and is in line with a pragmatic realist philosophy of science.

In this thesis, it is important to define the boundaries for the case studies in each of the research papers. As illustrated by Yin (2018), there are many ways to define and set the boundaries from single case studies to comparative case studies or case studies with sub-cases. Yin (2018) outlines four types of designs:

- Type 1: Single-case (holistic) designs
- Type 2: Single-case (embedded) designs

- Type 3: Multiple-case (holistic) designs
- Type 4: Multiple-case (embedded) designs

In this thesis the starting point is the project as a boundary for the case study. Two main wind power projects are used as case studies. The boundaries for the case studies vary according to the level of analysis in the different research articles. As indicated in Table 1-2, the papers include both in-depth single case studies with embedded sub-cases (Paper 3), multiple-case designs (Papers 1, 2, & 4) as well as multiple-case designs with embedded sub-cases (4).

The comparative element is an important dimension of the analysis in this thesis. Whether the comparison is between the two projects, their organization and their context or whether it is between the different phases or learning spaces in the projects. As argued by Yin (2018), replicability is an important aspect of using multiple case studies and therefore the theoretical framework for analysis across cases is crucial. Please see each paper for a full discussion of case selection and rationale as well as the theoretical frameworks that can allow for replicable comparisons.

Table 1-2 Overview of case study methods included in the thesis

Paper	Method	Research case	Data
1	Cross-sectoral analysis	Four sub-sectors of RE sector in Kenya, large grid-connected wind, large grid-connected solar, small solar, small wind	Document analysis of sectoral dynamics and projects in pipeline
2	Multiple, holistic case design	Adama wind power project, Bui hydropower project, Garissa solar power project	Interview material + document analysis
3	Single, embedded case design	Lake Turkana wind power project, with phases of the project as sub-cases	Interview material + document analysis
4	Multiple, embedded case design	Adama wind power project and Lake Turkana wind power project, with different learning spaces as sub-cases	Interview material + document analysis

The results of case studies and their generalizability are focused on theoretical or analytical generalizations. The nature of case studies does not lend to statistical generalization, they are rather focused on corroborating, modifying, rejecting or otherwise advancing theoretical concepts from the research design (Yin, 2018). Reflections on the theoretical contributions of the case study data are presented both in the individual papers as well as in the concluding discussion of this synthesis.

The following section will explain and discuss in more detail the methods for data collection and analysis.

1.4.3. METHODS FOR DATA COLLECTION AND ANALYSIS

The thesis is based on in-depth research as part of the IREK project on innovation and renewable electrification in Kenya. It makes use of many different forms of qualitative data that were created and obtained throughout the research period. During the period 2016-2019, three trips to Kenya were completed, as well as a trip to Ethiopia in 2017 (see Table 1-3). During these trips the main body of empirical data from interviews was collected. However, during the entire research period from 2016 until write up, other forms of data were collected and used in the analysis. This includes field notes, observational data, project documents, reports, news articles, presentations and texts from websites, as well as audiotapes and transcriptions of interviews. However, the most prominently used data source is the qualitative interview, which gave the most insight into how actors in and around the studied projects interacted and related to each other.

A qualitative interview can be seen as a knowledge-producing conversation that is a central tool to obtain knowledge about others, including how they experience, think, feel and act in the world. The most widespread form of interviews is probably the semi-structured interview (Brinkmann, 2014). The semi-structured interview format allows for focus on a set of specified topics, while also making it possible for the interviewees to bring in new – and perhaps unexpected – insights (Bryman, 2012). Having the interviewees provide input on all the specified topics enables a deeper understanding of these aspects.

Table 1-3 Overview of fieldwork trips

Dates	Location	Activities
01. Feb 2017 – 11. Feb 2017	Kenya	Workshop, joint interviews
11. Sep 2017 – 08. Dec 2017	Kenya	Interviews, 1-day site visit to LTWP (including presentation, interviews and a tour of facilities)
29. Oct 2017 – 12 Nov 2017	Ethiopia	Interviews, ½-day site visit to Adama II (including interviews and a tour of the facilities, including entering inside a wind turbine), presentation at ASTU
27. Jan 2019 – 02. Feb 2019	Kenya	Workshop, follow-up interviews

During the research period, several rounds of interviews were conducted (see Table 1-3), and in total 41 semi-structured qualitative interviews (see Appendix 1A), including with members of government departments, the national utilities, project developers, contractors, funders, civil society and community liaison officers. Some interviews were conducted jointly with colleagues in the IREK project, and others were conducted by the author alone. The research process included project site visits to the Lake Turkana Wind Power project in Kenya and the Adama II project in Ethiopia in 2017.

The next sections will briefly describe the planning and logistical challenges of data collection regarding the two wind power projects. The planning included gaining research permits, identifying gatekeepers who could arrange access to the sites and planning and conducting interviews with key actors with an overview of the projects across their lifetimes.

A particular challenge during data collection was to arrange site visits to the two case study project sites. The nature of the projects, their status as power plants, and, in the case of LTWP the remoteness of the site, meant that gaining access required permissions. For the LTWP visit it was necessary to reserve a seat on the flight which brings staff to site for rotational shifts. The LTWP visit was further delayed because of political tension in Kenya following the 2017 August presidential elections that were annulled and required a new election in October. All meetings and activities were temporarily suspended due to the uncertainty this caused. For the Adama II site visit, a partnership with Adama Science and Technology University (ASTU) was essential. There was a degree of suspicion of foreign researchers and a personal contact who could verify the research background of the thesis was critical to gaining permission to visit. Once the partnership was established, a key expert from the university consulting team to the Adama II project was able to facilitate interviews, meetings as well as the site visit.

Site visits present a one-off chance for ‘contextual learning’, seeing the physical site, technologies in use (or in the case of LTWP, the final construction (delayed) to be put in use), and meeting staff on the project. However, due to the nature of the lifecycle of wind power projects, site visits allowed for interviews with project managers on site, but other individuals from sub-contractors and key actors during different phases of the projects had to be identified and interviewed at other times. A site-visit lasted ½-1 day and included tours of the facilities, presentations and short conversations with technicians on site. While the overall organization of the projects being examined was known before entering the field based on the organizational information available in public documentation and websites about the project, the main challenge of the data collection phase was snowballing to identify individuals and their contact details for contractors and sub-contractors in the project. Web-searches were used to identify names of persons at each organization, and this list was kept in mind and at each interview, snowballing techniques were used to ask respondents whether they could help me to identify someone appropriate. There was a challenge in identifying respondents from sub-contractors during the construction phases, as these individuals would have moved on to other projects. The data collection therefore focused on getting in-depth interviews with the project managers who had an overview of contracts and collaboration across contractors to gain insights into those relations. There were also cases of individuals who had been working in certain roles in one organization, changing positions, e.g., transferring from KenGen to LTWP, or from Vestas to LTWP, and thereby having knowledge from both organizations' involvement.

Overall, the strategy can be identified as purposeful sampling, i.e., where certain groups, settings (e.g., the site visit) and individuals (key contacts at each contractor or sub-contractor) are sought out based on the assumption that this is where the processes being studied are most likely to occur (Denzin & Lincoln, 2005). According to Overton & van Diermen (2003), purposeful sampling occurs when the researcher makes a judgement on whom to include in the sample. This is possible when the researcher has a clear idea of what sample units are needed, and then approaches potential sample members to check whether they meet eligibility criteria (Easterby-Smith et al., 2008). In this case, the eligibility criteria were based on firstly identifying the main contractors of the projects, and secondly, being able to interview someone with an overview of the work completed as part of the contract, e.g., at project manager level. Therefore, purposeful sampling entails an assessment of potential respondents and a subsequent choice on whether to include them in the final data sample. The interviews were recorded and subsequently transcribed – thereafter, the transcriptions were linked to the relevant concepts in a coding process. For each article, separate tables were made to identify relevant passages from documents, interviews and notes that related to the central concepts of each paper and analysis. Final decisions on which data is included in the research articles can be found in each paper.

The research papers are a combination of co-authored and single-authored papers. The contributions to the co-authored papers are based on empirical data collected for this thesis, which has been combined with data collected by other researchers for e.g., papers 1 & 2, where case studies of other renewable energy projects and sectoral dynamics have been based on other PhD projects. Papers 3 is solely based on data collected for this thesis. The collaborative nature of the co-authored papers reflects the cooperation in the IREK project, where each author contributed with in-depth knowledge and data on the respective areas of focus. Furthermore, paper 1 benefitted from data collected during joint interviews. The co-authoring teams discussed both theoretical frameworks and conceptual analysis across the cases and for each individual case contribution.

The research also includes extensive content analysis of sources such as policy and legal documents, minutes of public meetings, media articles, speeches by government and other energy stakeholders and parliamentary transcripts. The papers present data relating to project ownership which is drawn from an extensive compilation of publicly available sources including newspaper articles, industry specific publications, project and company websites and company reports.

There are certain methodological challenges to collecting data on the lifecycle of projects with more than 10 years of development (such as LTWP) and an expected operational lifetime of 20 years. There is a limitation that interviews could only be conducted during a certain time period within the project lifetime. However, the interviews provide a window into the project's past and future, and the analysis of operational phases are based on descriptions of the contracts between technology providers and operational units. Collecting data on aspects of different phases of projects relied on participant's memories and publicly available documentation. Comprehensive measurement of capability accumulation would be based on continuous data collection with a baseline of capabilities at the project's start and an ex-port evaluation of learning outcomes. However, such an assessment was not the purpose of this thesis – instead the focus has been on highlighting examples of capability building by different types of actors in an exemplary network.

1.5. SUMMARY OF RESEARCH PAPERS

The following section summarises and provides insights into the findings of the four research papers included in this thesis (see also Table 1-4).

1.5.1. PAPER 1: TECHNOLOGICAL SHAPE AND SIZE: A DISAGGREGATED PERSPECTIVE ON SECTORAL INNOVATION SYSTEMS

This co-authored paper (Hansen, Gregersen, Lema, Samoita & Wandera, 2018) focuses on sectoral innovation system features across small-scale (mini-grids) and large-scale (grid-connected) deployment paths for wind and solar power technologies in Kenya. In examining the differences in terms of size and shape across and between these sub-sectors, it discusses the definitions and boundaries of these renewable energy 'sectors'. The key research question is:

- *How do wind and solar markets in Kenya differ in terms of development and organization, both across and within sectors?*

The paper explores and describes how the development and diffusion of solar PV and wind technologies evolve in these sub-sectoral systems by mapping out current status and trends. While there are profound differences between low carbon technologies (Lema et al., 2015), the differences within solar PV and wind energy as overarching technological categories are equally profound. For example, the notion of 'solar technology' can be used as an umbrella term to describe everything from solar-powered lamps, solar home systems, and utility-scale solar power plants. The commonality across these technologies is the use of solar panels as the underlying source of electricity generation. However, significant differences exist in respective users, producers, investors, actors, prices, scales, R&D intensities, value chains, technical characteristics, and competing technologies of these systems (Adebowale et al., 2014). Understanding such differences in sectoral confirmations helps identify dynamics that otherwise go unnoticed and as a result, this paper argues that each of the sub-categories of the overall 'technology shape' may be more appropriately considered units of analysis. Using the sectoral innovation system perspective, the paper describes the characteristics of each sub-sector, their drivers and barriers, and discusses the similarities and differences between them.

Following the sectoral innovation system perspective as set forth by Malerba and Nelson (2011), three main dimensions are used to guide the analysis of the four sectors: knowledge and technologies; actors and networks; and institutions. This perspective shows that in terms of the key system dimensions, there is a greater similarity between large-scale wind and solar projects (size), than between projects within the same technologies (shape). The large-scale projects are characterized by scientific knowledge bases (R&D), with actors with EPC experience or turnkey contracting playing a large role. The projects are capital-intensive, involve management expertise and power purchase agreement (PPA) negotiations, and generally involve foreign actors in terms of both technology and expertise, as well as investments. The small-scale wind and solar mini-grid sectors are markedly characterized by decentralized electrification efforts and are highly dependent on tariff structures and cross-subsidies. The rural electrification domain is connected to discussions about grid extensions and sees many donor-driven hybridization efforts (particularly in solar). However, there are also significant differences in regulation and policy frameworks for wind and solar mini-grids. Using the SIS perspective at a disaggregated level has in fact highlighted the coexistence of different innovation systems within broadly defined sectors.

These conclusions have important implications both theoretically and practically. Firstly, it indicates that a disaggregated (sub-sectoral) focus is more suited to policy-oriented work on the development and diffusion of renewable energy than aggregate-level analysis of entire sectors. Such as approach is highly relevant for the analysis of pathways – or directions – of development in the energy field. Secondly, this study suggests that policy makers should think about how they want to shape electrification pathways across the sizes and shapes outlined, rather than implement 'one-size-fits-all' policies for renewable energy. Tailor-made policies can help shape the dynamics of each sub-sector, and actors can decide which aspects should be enhanced, through, for example, appropriate tariffs and incentives as well as broader technical and procedural regulations.

1.5.2. PAPER 2: CHINA'S INVESTMENTS IN RENEWABLE ENERGY IN AFRICA: CREATING CO-BENEFITS OR JUST CASHING-IN?

This co-authored paper (Lema, Bhamidipati, Gregersen, Hansen & Kirrchhner, 2021) focuses on spillovers and linkage development effects of Chinese renewable energy investments in sub-Saharan Africa. The rapid increase and likely future growth of

Chinese involvement in large-scale renewable energy projects is one of the peculiarities of Africa's renewable energy sector. Insights from other infrastructure, utility and resource-extraction sectors in sub-Saharan Africa suggest that China is pursuing a specific Chinese enclave model of investment in regard to finance, turnkey project development and the importation of labour and equipment from China (Kaplinsky & Morris, 2009; Sanfillipo, 2010; Wegenast, Strüver & Giesen, 2019). The guiding research question is:

- *What is the potential for benefitting from Chinese renewable-energy investments in terms of employment, localization of value chain and technological learning?*

The analysis is based on an examination of three specific Chinese projects in hydro (Ghana), wind (Ethiopia) and solar (Kenya). By providing in-depth analysis of co-benefits, the paper aims to inform a discussion of the conditions and policy measures which may maximise local benefits of these investments. The paper includes a broader examination of renewable-energy investments with Chinese characteristics (key actors and their relationships) which is undertaken by dissecting macro-data about China's involvement in the chosen renewable-energy sectors in sub-Saharan Africa. The paper develops a framework for explorative research that aims to capture the main elements that characterise Chinese green-energy infrastructure projects and their economic co-benefits. It is based on 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.

The findings show that the three projects differ significantly in their technical nature, but using the framework developed in the paper, it is possible to bring them together for analysis and comparison. Direct job creation was significant but varied throughout the projects' phases. Both the nature of jobs and the (limited) involvement of local suppliers have negative implications on the opportunities for technological learning. In general, the domain in which the most significant capability-acquisition and 'knowledge transfers' took place, was the operational phases of the 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 construction phases. While the use of local labour was significant, the use of local manufacturing and services and the development of local expertise capabilities was limited. 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 function.

Empirically, the research shows that local institutional and economic conditions as well as the nature and organization of the investment project have important implications for economic co-benefit creation. Theoretically, the study provides insights on the potential for co-benefits in low- and middle-income countries where strategies and policies for greening with renewables are recent and practical implementation is dependent on significant in-flows of capital and technology. The findings emphasize the highly restricted nature of such co-benefits. The findings also highlight the significant challenges associated with the notion of green latecomer development and sustainable industrialization in Africa.

Practically, this study emphasizes that an active and directed policy approach needs to be devised for maximizing co-benefits of renewable energy investments. The findings indicate that significant co-benefits will only arise with substantial local involvement in the high value-adding and more knowledge-intensive phases of the infrastructure delivery process.

1.5.3. PAPER 3: LOCAL LEARNING AND CAPABILITY BUILDING THROUGH TECHNOLOGY TRANSFER: EXPERIENCES FROM THE LAKE TURKANA WIND POWER PROJECT IN KENYA

This single-authored paper (Gregersen, 2020) provides an in-depth case study of local learning and capability building in the Lake Turkana Wind Power project in Kenya. The focus is on where and when local learning occurs through technology transfer. The paper contributes by investigating the variety of technology flows in wind power projects, particularly project characteristics that may or may not lead to more opportunities for local learning and capability building. The study takes a project as its point of departure and applies core ideas of technology transfer and interactive learning as central to the accumulation of innovation capabilities. The main research questions addressed in this paper is:

- *What are the opportunities and limitations for local learning and capability building through technology transfer in large renewable energy infrastructure projects?*

The analysis is based on an expanded version of Bell's (1990, 2007, 2012) simple heuristic of the qualitative content of technology transfer. The expanded version allows the paper to explore the multiplicity of actors and phases in the project. The framework thus highlights the spectrum of flows of technology from 'hardware' to 'software' and emphasizes that technology transfer flows are dynamic and not necessarily parallel or unidirectional. Furthermore, the framework illustrates the importance of the variation in contexts of interactions across the project phases.

The findings show variations in the interactions in the planning, construction and operations phase of the project. While the learning opportunities in the planning phase are characterized by multi-directional loops of interactions between a diverse set of actors, the centrally organized construction phase has fewer interactions and learning opportunities. The operations phase is highly characterized by intra-organisational training and learning opportunities for wind turbine maintenance. Some of the limitations to the extent of transfer include the degree to which learning occurs within and organization or across organizational boundaries as well as a lack of relevant knowledge stocks of some actors. Furthermore, many key actors' restricted involvement across the project phases limits long-term capability accumulation. Overall, the cumulative nature of capability building the project is found to be mainly intra-organizational across the phases of the projects.

The findings show that multiple supplier-user relationships occur during the project lifetime. They show where bidirectional or unidirectional interactions occur or where they are completely absent. These variations have direct implications for learning opportunities and limitations. High entry barriers for local firms limit local learning when the choice of subcontractors prioritizes international track record and experience.

By reviewing the opportunities and limitations for interactive learning among actors in the project, the paper highlights the micro-nuances and dynamic nature of technology transfer by illustrating the multiplicity of actors and knowledge flows taking place in the distinct phases of the wind power project. The nature of the phases and the ways in which they are organized have important implications for how interactions involve different technology flows or knowledge stocks. The paper brings forth a discussion of who is learning what in the project and in what directions capabilities can be accumulated based on this example of a wind power project.

1.5.4. PAPER 4: INTERACTIVE LEARNING SPACES: INSIGHTS FROM TWO WIND POWER MEGAPROJECTS

This co-authored book chapter (Gregersen & Gregersen, 2022) uses the lens of 'interactive learning spaces' to understand how interactions between different stakeholders in a megaproject can lead to the accumulation of technological and managerial capabilities. The chapter uses two case study wind power projects in Kenya and Ethiopia. The projects offer interesting and different examples of the types of learning spaces in which the transfer of both formalized and tacit knowledge can occur. Often such large infrastructure projects generate several local low-skilled jobs related to the construction phase but very few local high-skilled jobs (as also highlighted in Paper 2 above). Management and engineering jobs are often supplied from abroad together with key technologies. Nevertheless, this chapter shows that a deliberate creation of interactive learning spaces can be one way to establish, maintain and further develop local high-skilled jobs in relation to large turnkey infrastructure projects, even with key technologies imported. The concept of interactive learning spaces is used to explore the research question:

- *How do interactive learning spaces develop in the institutional settings within and around projects?*

The chapter builds an analysis of the two wind power projects structured according to two types of interactive learning spaces (Arocena & Sutz, 2000). One is a project management interactive learning space related to the project development and construction stages of the wind parks. The other is an interactive learning space related to the operations and maintenance phases of the projects. In each case, the chapter introduces the specific context and institutional settings, identifying key actors. Furthermore, the chapter analyses how a proactive strategy of creating an interactive learning space can spur capability-building in the two different types of learning spaces.

Looking across the two cases there are similarities and differences concerning where and under what institutional setting the wind power projects have created local interactive learning spaces with opportunities for skills upgrading and local capability-building. In large complex infrastructure projects, multiple organisations and complex interactions are involved, and in principle all actors may gain experience and obtain new or adjusted knowledge that may be accumulated and used within the project as it develops and/or is transferred to another context. While such learning by doing, using and interacting is key as it emerges and takes place everywhere all the time during a concrete project, it raises an important question as to whether learning spaces can be deliberately designed to support skills upgrading and local capability-building in the long run. While project-based construction is necessarily interactive and problem-solving, the two project cases show important differences in the way learning spaces can be designed and shaped to proactively contribute to a desired future. The Adama case in Ethiopia has an institutional setting supporting high-skilled knowledge transfer, the Lake Turkana project did not have a similar involvement of universities or other national public knowledge institutions. Instead, skills upgrading and capability building were regulated by contractual agreements between the project managers and sub-contractors. To secure that knowledge transfer and experience-based learning become locally rooted may be more difficult under such an institutional construction. In both cases, the learning spaces for maintenance are characterized by efforts to codify knowledge through manuals and tailored training programmes. However, the need for other modes of learning is shown in the complementarity of on-the-job training programmes and buddy systems, that foster informal communication and sharing. Finally, the chapter discusses the inclusivity/exclusivity of the different learning spaces, reflecting on the more inclusive nature of project management learning spaces, and the exclusive nature of the maintenance and operations learning spaces.

This chapter contributes theoretically to the understanding of the organizational learning cycle of wind power projects, and that different phases can have different learning spaces, depending on the actors involved. It raises considerations on issues of directionality, distribution, and diversity of learning spaces. It also emphasizes the importance of managing and supporting learning spaces in wind power projects. Through deliberate creation of interactive learning spaces, it is possible to establish and further develop local high-skilled jobs in projects where key technologies are imported.

1.5.5. SUMMARY TABLE

Table 1-4 below provides an overview of the papers summarized above, the main theoretical frameworks they address, the papers' role in the overall research framework, researchs questions, methods, data and publication status.

Table 1-4 Summary table

	Paper 1	**Paper 2**	**Paper 3**	**Paper 4**
Title	Technological shape and size: A disaggregated perspective on sectoral innovation systems in renewable electrification pathways	China's investments in renewable energy in Africa: creating co-benefits or just cashing-in?	Local learning and capability building through technology transfer: Experiences from the Lake Turkana Wind Power project in Kenya	Interactive learning spaces: Insights from two wind power megaprojects
Authors	Hansen, Gregersen, Lema, Samoita and Wandera (2018)	Lema, Bhamidipati, Gregersen, Hansen and Kirrchhner (2021)	Gregersen (2020)	Gregersen and Gregersen (2022)
Theory	Sectoral innovation systems	Economic co-benefits in terms of spillovers and linkage development effects	Evolutionary economic perspective of technology transfer	Interactive learning spaces
Role in research framework	Focus on size of projects and the consequences for sectoral innovation dynamics	Focus on spillovers and linkage development effects of Chinese RE investments in SSA	Focus on local learning through technology transfer (knowledge stocks and learning flows)	Focus on how interactive learning spaces are created or emerge and can disappear

Research question	How do wind and solar markets in Kenya differ in terms of development and organisation, both across and within sectors?	What is the potential for benefitting from Chinese renewable-energy investments in terms of employment, localisation of the value chain and technological learning?	What are the opportunities and limitations for local learning and capability building through technology transfer in large renewable-energy infrastructure projects?	How do interactive learning spaces develop in the institutional settings within and around the projects?
Research case	Large wind power sector in Kenya	Adama wind power project in Ethiopia, Bui Dam project in Ghana, Garissa solar power project in Kenya	Lake Turkana Wind Power project	Adama wind power project in Ethiopia, Lake Turkana Wind Power Project in Kenya
Method	Cross-sectoral analysis	Comparative case study	In-depth single case study	Comparative case study
Data	Interview data and document analysis	Interview data and document analysis	Interview data and document analysis	Interview data and document analysis
Status	Published (Energy Research and Social Science)	Published (World Development)	Published (Innovation and Development)	Published (book chapter)

1.6. CONCLUDING DISCUSSION

The following sections will reiterate the overall research question of the thesis, discuss how the key findings respond to this both individually and combined, outline the theoretical, empirical and practical contributions of the thesis and finally reflect on the limitations and avenues for further research.

1.6.1. KEY FINDINGS AND CONTRIBUTIONS TO INNOVATION AND DEVELOPMENT RESEARCH

This thesis has examined the dynamics of capability building that are required for the localization of economic activities and development of local capabilities for designing, constructing and supplying renewable electrification infrastructure such as windfarms. Building on an evolutionary perspective of technology, innovation and development, the thesis has unfolded why, how and through which mechanisms technology and innovation capabilities can contribute to sustainable industrialization. The thesis has shone empirical light on the process and complexity of capability building across and within different areas of expertise as well as across and within phases of wind power projects. This complexity poses a challenge for a continuous and cumulative process of building capabilities, which in turn poses a challenge for learning from such projects. Ultimately, this also limits the extent to which they contribute to sustainable industrialization in terms of enhanced innovation capabilities. However, the thesis has also contributed to an enhanced understanding of how learning spaces can be actively created and shaped, for example through contractual obligations, proactive strategizing about localization of activities and a combination of codified and tacit modes of learning, to overcome these challenges.

The overall research question was the following:

- *How can large wind power projects contribute to build technological and organisational capabilities for sustainable industrialisation in Kenya and Ethiopia?*

The answer to this question was explored in a multifaceted and complex analysis through four research papers using case studies of wind power megaprojects from Kenya and Ethiopia. The thesis contributes with a combination of theoretical frameworks, which underscore that learning, and technology transfer should in this context be understood as part of an interactive and interdependent rather than a linear process. The thesis uses lenses that tend towards more holistic and interdisciplinary approaches, with an understanding of the historical and evolutionary perspectives. Each paper conveys findings that help in part to answer this question.

Paper 1 contributes to the answer by describing the large wind power sector in Kenya – its knowledge and technologies, actors and networks and institutions. Through a comparative analysis with three other sub-sectors in the Kenyan renewable energy sector, this paper argues for a disaggregated focus for policy regarding the development and diffusion of renewable energy technologies rather than aggregate-level analysis of the entire sector. In terms of the capabilities involved in the large wind sub-sector, the paper highlights the importance building capabilities within e.g., technical and engineering-based disciplines, as well as contract and legal expertise. The paper thus brings together meso-level analysis of sub-sectors with a discussion of the structural conditions and incentives that shape wind power projects.

Paper 2 contributes to answering the overall research question by exploring the extent to which job creation, value chain localisation and technological learning are determined by the model of investment in large renewable energy projects. The paper opens for a discussion regarding the conditions and policy measures that may maximise the local benefits of renewable energy investments. The paper brings together micro-level focus of capability building in projects with contextual and structural issues regarding incentives and power asymmetries in the negotiation of project conditions.

Paper 3 contributes to answering the research question by taking an in-depth look at which actors interact in different phases of a wind power project. In conducting such a micro-level analysis of relations in a project and the wider system in which it is embedded, this paper elucidates the challenges of cumulative capability building across distinct phases with different key actors in wind power projects. It discusses the multiple points where capability accumulation can begin and the different directions in which this can happen. This is an important insight for policy making to foster learning and capability building – in which actors and key directions is capability building of higher priority? What is of strategic importance? It shows that potentially accumulated capabilities can be wasted without resources and a deliberate strategy to nurture them.

Paper 4 contributes to the overall research question by examining different interactive learning spaces that arose or were created in two different wind power projects and policy contexts. This paper gives concrete examples of how decision makers can outline and shape clear learning spaces that create distinctive types of interactions with the aim of capability building. It provides important nuances to the discussion of strategically supporting learning and capability building by comparing and contrasting reactive and proactive instances of shaping learning and discussing the inclusivity vs exclusivity of spaces for learning.

Overall, the findings focus on the importance of fostering and shaping forward pathways for the accumulation of capabilities. The different theoretical and conceptual angles and combinations of levels of analysis and frameworks highlight the interplay between micro-level dynamics of capability building - within firms, within projects, across organisational boundaries and across phases of project – and the meso-level dynamics shaped by structural conditions and incentives. This thesis distills three key insights regarding the process of capability building through wind power megaprojects.

The first relates to ideas of *continuity and cumulativeness* in capability building and learning. The theoretical foundations of this thesis stress the cumulative process of capability building – learning is largely seen as the process of adding new capabilities to existing ones in an intentional manner. This thesis has shown that the many different knowledge bases and areas of expertise that are in play in planning, constructing and operating a wind power plant challenges the cumulative efforts to learn across and even within the phases of projects. This is both due to the distinctive nature of the phases and the contractual obligations of actors. The thesis therefore urges us to think more about how to ensure continuity and accumulation of capabilities when projects and their economic gains (beyond power production) are of temporary nature. The thesis has provided some insight into accumulation of capabilities through interactive learning spaces but raises further questions about what happens when these are shut down. These insights suggest that systemic learning from project to project could be supported by creating or opening learning spaces that are not bounded to single investment projects. Ultimately, it is important to foster a more continuous learning process in order to build innovation capabilities for wider sustainable industrialisation.

The second key insight relates to *actor diversity* in learning and capability building processes. This thesis has provided detailed insights into which activities are undertaken by which actors. Importantly, it has looked at capability building beyond firms, but essentially among a range of actors in related innovation systems, or e.g., in specific interactive learning spaces. This includes government actors, utilities that own power plants, universities (consultants) and contractors within the project. The exclusivity of certain learning spaces that for example exist only within the organisational boundaries of one firm is a challenge for wider capability building in certain areas of expertise. The findings also make distinctions between local and foreign actors and have shown that large wind power projects are highly characterised by the role that foreign EPC contractors and technology suppliers play. While local firms have limited opportunities to involve themselves in areas where their baseline capabilities are lacking, other local actors, most specifically decision makers in the energy sector, can influence the way in which other actors, e.g., from the education sector can be included. This suggests that capability building by government actors and the role of policy learning is equally relevant for renewable electrification's contribution to wider sustainable industrialisation. Overall, this opens for more thinking which firmly integrates the issue of diversity of actors, and relatedly the inclusiveness or exclusiveness, participating in capability building and learning processes.

Finally, the third insight relates to the question of *directionality* of pathways for capability accumulation. The thesis situates the study of capability building in the context of learning for renewable electrification and more broadly in the context of learning for sustainable industrialisation. It has demonstrated that part of the complexity of capability building through renewable electrification relates in fact to the multiplicity of ‘starting points’ from which capability building can be fostered. This becomes clear when we examine the micro-level dynamics, of sub-sectors, of projects and even of phases or specific learning spaces within projects. This calls for more detailed strategizing about the prioritisation of synergies between renewable electrification and sustainable industrialisation. In this regard, it is important to determine what the goal of learning from projects should be. This thesis has identified areas for capability building pathways beyond the production and manufacturing of wind turbine components, with an example of a pathway for capability building regarding project planning and management of wind power projects. Other pathways for capability accumulation may start in different service areas such as maintenance, training, feasibility studies or other technical areas. Overall, these results and insights indicate the need for thinking, strategizing and planning for collective learning beyond individual projects as a part of wider learning-based sustainable industrialisation strategies.

These key insights call for an integrated understanding of learning and capability building through renewable electrification. They have important theoretical and empirical implications and the following sections will outline these further.

As shown earlier, existing frameworks to understand the process of learning and capability building from technology transfer have focused on manufacturing settings, but there is a much more limited understanding of that process in project settings, let alone in renewable electrification. The main *theoretical* contribution of the study is thus to provide a tailored, novel and multi-level conceptual framework for studying learning and capability-building in the electrification process that concerns large projects. The novelty lies in the nested perspective that is brought forth by the integrated analysis of systems, projects and learning spaces as described earlier. Subsequently, the papers each provide distinct insights into each of these levels and how they influence capability building and learning – where and why it may occur or be restricted in specific institutional and policy contexts. Together they contribute to the literature on innovation and development with a comprehensive and scalable view on learning through electrification. These insights further the theoretical debate about the links between (and over time, the co-evolution of) technological and organisational capabilities and governance structures. Furthermore, they suggest that it is crucial to consider the cumulative aspects and corresponding limitations of capability building in emerging sectors such as wind - an issue that is relevant across multiple renewable electrification contexts and is important for the process of learning and innovation in relation to wider sustainable industrialisation.

There is substantial existing work on a range of aspects regarding rural and renewable electrification in Africa, often with a focus on solar PV. Studies have examined decentralized renewable energy systems (Pedersen, 2016; Ahlborg & Hammar, 2014; Kemausuor, Sedzro & Osei, 2018), dissemination of off-grid technologies for renewable electrification (Amuzu-Sefordzi et al., 2018), renewable energy financing (Chirambo, 2016; Baker, 2015), and even the disposal problem of e-waste from renewable electrification (Bensch, Peters & Sievert, 2017; Hansen et al., 2022). Yet there has hitherto been a limited understanding of how large-scale projects, and wind power more specifically, may contribute to learning and capability building through renewable electrification in Sub-Saharan Africa. *Empirically*, this thesis has therefore contributed by illuminating these aspects of wind power megaprojects. It has provided multiple concrete examples that have been examined in both in-depth single case studies and multiple, embedded case studies and which have thus enabled comparisons across multiple levels of analysis. As such, this thesis has provided novel, in-depth empirical insights into organizational-, project-, and system-level learning processes within and across phases of wind power projects. This thesis has shown that large wind power projects can contribute to building organizational and technological capabilities if interactive learning spaces are purposefully created and nurtured, for example in the case of Adama II's project management learning space. It has integrated multiple levels of analysis to map actors and their relationships in distinct phases and areas of capability building within two of Africa's largest wind power projects.

This thesis contributes to a limited, but emerging literature mapping the types of investments being made in wind energy across the African continent (Mukasa et al., 2015). Existing knowledge about the two case study projects includes insights regarding technology transfer from wind power projects in Ethiopia (Chen, 2018), the exclusionary effects of the Lake Turkana Wind Power project in Kenya (Cormack & Kurewa, 2018), the 'development' discourse and implications for community land surrounding the Lake Turkana Wind Power project in Kenya (Achiba, 2019), and the policy frameworks for wind energy in Kenya (Kazimierczuk, 2019). This thesis carves out a specific contribution by showing that learning and capability building from wind power projects for wider sustainable industrialization is an interactive process that depends on the pre-existing capabilities of key actors as well as deliberate investments in learning in successive phases of the case study projects. An empirical focus throughout has been on issues of interactions and relations – the research not only identifies key actors across multiple phases of projects but also examines how and with whom they interact.

The following section will elaborate on the practical implications of these findings for renewable electrification in broader contexts.

1.6.2. PRACTICAL IMPLICATIONS FOR RENEWABLE ENERGY PROJECTS

Overall, the thesis provides a deepened understanding of how and where learning and capability building opportunities arise in large wind power projects – this is important for bridging the gap between ambitions to couple renewable electrification efforts with economic development and sustainable industrialisation. Practically, the findings contribute to a better understanding of the importance of creating opportunities for learning, knowledge transfer, and co-benefits. The degree of attention and proactive strategies related to learning has varied significantly across the different actors and phases of the projects examined. Importantly, the findings emphasize the systemic nature of learning and capability building – and indicate that the more inclusive learning spaces can be, the wider the learning opportunities from projects.

Solving complex societal challenges requires attention to the interaction of socio-economic issues with politics and technology, smart regulation and the feedback processes that take place across the entire innovation chain or system. Mazzucato highlights cross-disciplinary, cross-sector and cross-actor policies as key (Mazzucato, 2018). Borrás & Edler (2020) have emphasized that the role of governments in the transformation of socio-technical systems remains underexplored in the context of advanced economies, let alone in the Global South. They argue that the transformative agency of the state is exercised through mixes of roles to influence, promote or inhibit transformative processes. This thesis has drawn insights from East Africa and has illustrated the particular position of projects as a meeting point between the top-down role of government influence and the more bottom-up role that firms and/or projects can have in shaping transitions. Public authorities are key in terms of regulating and supporting renewable electrification. In some contexts, public authorities act as lead firms and require project management capabilities to manage the investments in renewable energy projects. Therefore, policy learning is vital for ensuring that opportunities for sustainable industrialisation arising from electrification processes are realised. Such learning occurs as a part of a policy process which engages a wide range of individuals, or policy actors, over time. The following suggestions and insight are intended to feed into such a process.

For *project owners and managers*, there are specific insights into the opportunities and limitations for fostering learning across and within different phases of the projects:

- Interfaces in the projects can form the starting point of interactive learning spaces and can be designed to foster different types of learning.
- Interactions across organizational boundaries present opportunities for more inclusive learning by a diverse set of actors
- Phases of projects present limitations for cumulative learning unless carry-over is planned.

For *policy makers and funders*, there are insights about how to ensure co-benefits and regulate/set requirements for involvement of local actors and institutions:

- Project design can become more conducive to learning when regulation promotes interaction with local actors (e.g., incentivize the involvement of the education sector or set local content requirements)
- Financial agreements which specify issues regarding technology selection have a large influence on the characteristics of related learning spaces which occur in particular in the operations and maintenance phase of projects
- Further efforts can be made to integrate frameworks for the selection and shaping of renewable energy projects with those for industrial development and education and training
- The selection process for projects can be adapted to focus on broader criterion than energy production itself such as capability building and learning

For *NGOs and civil society* at large, this thesis has provided insights that can be used to argue for more inclusive and learning-based approaches to project organization of specific projects, but also can be integrated into larger debates about just and inclusive access to sustainable energy:

- Further efforts can be made to proactively shape and create deliberate learning spaces – both at project level but also beyond the projects for example for policy learning involving civil society actors
- A constructive way to engage with shaping future renewable electrification projects would be to focus on removing the limitations for inclusive, learning-oriented project practices, for example by contributing to coordination and convening of learning from projects by gathering, documenting and sharing lessons for future projects.

The thesis thus firmly argues that despite the positive contributions of renewable energy technologies, policy makers and other actors need to think about how to design deliberate strategies to ensure local embeddedness and learning from sustainable projects. It suggests that policy makers can actively shape electrification pathways across projects and sub-sectors that can contribute to a learning-based sustainable industrialisation. To do so, decision-makers need to acknowledge and appreciate the cumulative aspects of local learning and the interactive nature of innovation, learning and technology transfer. This entails thinking about what causes discontinuous learning, where focus can be put on carry-over to enhance cumulative effects of capability building and how learning spaces can be created in more inclusive and holistic manners where a variety of actors in dynamic systems are engaged. The final section of this synopsis will discuss some of the limitations of this research as well as ideas for future research topics.

1.6.3. LIMITATIONS AND FURTHER RESEARCH

The thesis has strongly argued for and provided evidence of some of the potentials for learning and capability building from large wind energy projects for renewable electrification. The thesis contributes with a number of policy and practice implications as outlined above. The conclusions are derived from case studies of wind power projects in Kenya and Ethiopia, and the empirical contributions are very much related to the specific contexts in which these projects have unfolded. The policy and practice implications are therefore relevant specifically for wind power development in Kenya and Ethiopia, but also more generally for other renewable electrification contexts and megaprojects in the region. For example, the attainment of infrastructure project execution capabilities is relevant outside the specific domain of renewable electrification, that is, in building roads, ports, electricity distribution systems, etc. as well. Megaprojects such as the Lamu Port, South Sudan, Ethiopia Transport Corridor (LAPSSET), which consists of several key infrastructure projects, may face similar issues regarding opportunities and limitations for wider learning and capability building. Other renewable energy projects in the region include hydropower dams, large solar projects and geothermal energy projects. While Kenya for example has built considerable local capabilities regarding geothermal energy projects, insights on the subject of learning spaces and consolidating learning from projects are relevant in this regard. The recommendations regarding policy and practice can therefore be useful for stakeholders involved in not only energy projects in similar contexts but also other types of mega-infrastructure projects.

The theoretical and conceptual discussions are more generalizable, and the research has shown that there are commonalities across the dimension of large renewable energy projects and that the size of projects may be more important in this regard than the technology in question. The research has provided insight into the relevant socio-technical settings of projects and nuances across phases of projects. It has contributed to broader discussions of technology transfer and capability building. While the theoretical and conceptual findings have focused on the ways in which learning can be fostered and shaped, another dimension for reflection relates to the factors that limit or prevent such interactive learning. The findings have provided some insights into this, highlighting for example contractual obligations, language barriers between suppliers and users, and standard project management practices that focus on budget, time and quality (rather than integrating learning). To remove the most limiting factors may be a useful method to enhance learning and future research could explore this dimension further.

As mentioned in section 1.3, there were methodological limitations to studying capability accumulation in a limited time frame. Bell (2006, p. 33) has shown that there is a lack of focus on the dimension of time in studies of capability accumulation processes and that no studies can provide systematic evidence of how long it takes to move through any illustrative stages of capability accumulation beyond ‘decades, not years'. While the data collected sought to provide as dynamic a snapshot of the phenomenon in focus, a comprehensive measurement of capability accumulation would require a deliberate, longitudinal study and continuous data collection. Yet the findings provide micro-level evidence of the starting points of capability building and that some degree of accumulation can be identified over shorter periods as a result of deliberate, proactive strategies (as seen in the case of project management in Adama II). More broadly, however, and as argued by Bell (2006), the nature of research projects and funding is often limited to shorter time frames than would allow for extensive, longitudinal analysis. Yet, this is an important avenue for further research to pursue in order to feed into the formulation of longer-term government policy and strategy concerned with learning and the technological basis for sustainable industrial growth.

However, the improved understanding of the dynamics of capability building at the level of organisations, projects and sub-sectors provides the foundation for an improved and qualitatively different understanding of the mechanisms for learning for sustainable industrialisation at the aggregate level. Therefore, this thesis urges further research to focus on learning as a central part of the process of renewable electrification – as learning gains can have a more lasting effect on the change of economic development paths and more specifically renewable electrification paths. A better understanding of renewable electrification for sustainable industrialization must be grounded in a better understanding of the microlevel dynamics of learning and capability building that produce economic and technical change. This necessitates a better understanding of the link between policy learning and organizational and technological capability building.

In terms of theoretical avenues for further research, Paper 1 of this thesis has called for further research to investigate the 'structure' of sectoral systems and the kinds of policy mechanisms that may influence both co-existing and complementary sub-sectoral systems. There is scope for further research into interactions between and the co-evolution of sub-sectoral innovation systems. Paper 4 suggests that there is potential for further reflections on the concept of interactive learning spaces - this is a relatively understudied concept but an interesting one to operationalize ideas about continuity of learning as it can be useful for empirically exploring where learning is created, nurtured, shaped or perhaps shut down in defined contexts. Paper 2 has challenged stylized, dyadic ideas of technology transfer in which a technology user learns from a technology supplier and has rather contributed to the understanding of technology transfer as involving relationships and interaction in a wide range of actors. In particular, the bi-directionality of technology transfer is an interesting avenue for further research – and can draw inspiration from work by Lundvall (1985) on user-producer interaction. Papers 2 and 3 show that there is great potential for further research to bridge the capability view with literature on megaprojects – this would be a fruitful avenue to explore further methodological reflections on how to undertake case studies of such projects and explore the nature of the wind power project as a megaproject. The megaproject literature provides deeper insights into the contentious nature of megaprojects and could meaningfully be integrated with a capability perspective to examine issues of inclusivity vs. exclusivity of projects and the role of the relationship to local communities as emphasized by Cormack & Kurewa (2018) and Achiba (2019). A cross-cutting recommendation for further research is to consider more deeply the dimension of inclusivity as an important avenue for future research in itself; how to give voice, capabilities and rights to those excluded remains underexplored in the capability literature.

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APPENDIX 1A

Table 1A-1: List of interviews

No	Location[7]	Date	Duration	Title/function	Responding organisations
01	Kenya	07.02.2017	60 min	Assistant Manager, Energy Planning	Kenya Electricity Generating Company
02	Kenya	07.02.2017	60 min	Project Director	Frontier Investments
03	Kenya	08.02.2017	60 min	Senior Manager, Power Management	Kenya Electricity Transmission Company
04	Kenya	09.02.2017	60 min	Regional Director	Investment Fund for Developing Countries
05	Kenya	12.09.2017	95 min	Director	Lake Turkana Wind Power
06	Kenya	22.09.2017	45 min	Research Fellow	Strathmore Energy Research Centre
07	Kenya	25.09.2017	45 min	Principal Research Officer	Kenya National Innovation Agency
08	Kenya	26.09.2017	20 min	Chairperson	Kenya Renewable Energy Association
09	Kenya	27.09.2017	60 min	Chief Technical Officer	Lake Turkana Wind Power
10	Kenya	28.09.2017	140 min	Secretary	Association of Energy Professionals East Africa
11	Kenya	29.09.2017	1 hour	Director, Economic Regulation	Energy Regulatory Commission
12	Kenya	05.10.2017	30 min	Research Fellow	Stockholm Environment Institute
13	Kenya	10.10.2017	45 min	Director, Renewable Energy	Ministry of Energy and Petroleum
14	Kenya	12.10.2017	45 min	Project Director	Afrepen/ Energy, Environment & Development Network for Africa
15	Kenya	13.10.2017	85 min	Director	Lake Turkana Wind Power

[7] All interviews were conducted face-to-face unless otherwise noted

No	Location[7]	Date	Duration	Title/function	Responding organisations
16	Kenya	16.10.2017	50 min	Senior Manager, Service	Vestas
17	Kenya	17.10.2017	35 min	CSR Manager	Vestas
18	Kenya	19.10.2017	30 min	Business Development Manager	Kenya Association of Manufacturers
19	Kenya	19.10.2017	30 min	Energy Officer	Kenya Association of Manufacturers
20	Kenya	23.10.2017	35 min	Deputy Director, Renewable Energy	Ministry of Energy and Petroleum
21	Kenya	27.10.2017	60 min	CEO	Kurrent Technologies
22	Kenya	01.12.2017	90 min	Manager	Craftskills
23	Kenya	03.12.2017	30 min	Engineer	Kenya Electricity Generating Company
24	Kenya	03.12.2017	30 min	Technician	Kenya Electricity Generating Company
25	Kenya	05.12.2017	30 min	General Manager	Lake Turkana Wind Power
26	Kenya	05.12.2017	40 min	Chief Operations Officer	Lake Turkana Wind Power
27	Kenya	04.02.2019	50 min	Director	Lake Turkana Wind Power
28	Kenya – skype	04.02.2019	40 min	Senior Manager, Service	Vestas
29	Kenya – skype	05.02.2019	35 min	Founder, Programmes director	Friends of Lake Turkana
30	Kenya	06.02.2019	55 min	Deputy Director, Regulatory Research and Policy Analysis	Energy Regulatory Commission
31	Kenya – skype	14.02.2019	65 min	Project Manager	Entreprise Générale Malta Forrest
32	Ethiopia	08.11.2017	30 min	Assistant Professor	Adama Science and Technology University
33	Ethiopia	09.11.2017	50 min	Operations and Support Manager	HydroChina

No	Location[7]	Date	Duration	Title/function	Responding organisations
34	Ethiopia	09.11.2017	10 min	Technician	Ethiopian Electric Power
35	Ethiopia	09.11.2017	40 min	Assistant Professor	Adama Science and Technology University
36	Ethiopia	10.11.2017	80 min	Assistant Professor	Adama Science and Technology University
37	Ethiopia	13.11.2017	50 min	Energy Analyst	Ministry of Water, Irrigation and Electricity
38	Ethiopia	13.11.2017	55 min	Project Manager	Ethiopian Electric Power
39	Ethiopia	13.11.2017	20 min	Director General	Ethiopian Energy Agency
40	Ethiopia	14.11.2017	45 min	Repre-sentative	HydroChina
41	Ethiopia	16.11.2017	40 min	Senior Programme Manager	Danish Embassy

CHAPTER 2. TECHNOLOGICAL SHAPE AND SIZE: A DISAGGREGATED PERSPECTIVE ON SECTORAL INNOVATION SYSTEMS

ABSTRACT

The sectoral innovation system perspective has been developed as an analytical framework to analyse and understand innovation dynamics within and across various sectors. Most of the research conducted on sectoral innovation systems has focused on an aggregate level analysis of entire sectors. This paper argues that a disaggregated (sub-sectoral) focus is more suited to policy oriented work on the development and diffusion of renewable energy, particularly in countries with rapidly developing energy systems and open technology choices. It focuses on size, distinguishing between small-scale (mini-grids) and large-scale (grid-connected) deployment paths in renewable energy. We explore how the development and diffusion of solar PV and wind technology evolve in these sub-sectoral systems. We find that innovation and diffusion dynamics differ more between small and large than between wind and solar. This has important analytical implications because the disaggregated perspective allows us to identify trajectories that cut across conventionally defined core technologies. This is important for ongoing discussions of electrification pathways in developing countries. We conclude the paper by distilling the implications of these findings in terms of the requirements and incentive mechanisms that shape different pathways.

Key words: Sectoral innovation systems, electrification pathways, renewable energy, Kenya, mini-grids, diffusion, solar PV, wind energy

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2.1. INTRODUCTION

Kenya, like many other countries around the globe, is currently facing momentous energy decisions. With a low rural electrification rate and a large proportion of the population currently lacking access to electricity, increasing generating capacity and achieving 100% energy access is a key priority for the government. While the current electricity system relies mainly on hydropower, the expansion of renewable energy (RE) sources, especially wind and solar power, has been given a high priority in national policies such as the national development strategy Vision 2030 and the rural electrification master plan (REA, 2009; GoK, 2007).

Within the context of a rapidly developing energy system, Kenya faces a number of important technological choices in terms not only of which technologies to prioritise, but how to deploy them. The current policy frameworks have enabled a combination of government and private sector developments in the energy sector.

The concept of sectoral innovation systems (SIS) has been used to illuminate the factors affecting innovation dynamics within and across sectors. The SIS perspective is particularly concerned with highlighting sector-specific characteristics of industrial evolution (Malerba & Nelson, 2011). From the sectoral perspective, increasing attention is paid to RE sectors and their development. In this paper, we argue that it is crucial to take a closer look at the RE sector and what constitutes such a sector in order to push further the disaggregation of trends in the sub-sectors of wind and solar PV. In examining differences in terms of size and shape across and between these sub-sectors, we raise questions regarding the definitions and boundaries of these renewable energy 'sectors'.

Thus the key research question of this paper is: How do wind and solar markets in Kenya differ in terms of development and organisation, both across and within sectors? We answer this question by mapping out current status and trends across the mini-grid and large-scale market segments for wind and solar PV technologies respectively. Then we use the SIS perspective to describe the characteristics of each sub-sector, their drivers and barriers, and discuss the similarities and differences between them. As detailed and up to date information on the development and dynamics of the solar and wind markets in Kenya were found to be lacking, this paper seeks to bring together preliminary insights from research conducted in 2015–2016.

The paper is structured as follows. Section 2.2 introduces the sectoral innovation systems approach and its three main dimensions, which are used as the analytical framework for the research. Section 2.3 briefly introduces the research methods. Section 2.4 presents the results in the form of a mapping of current status and trends across the mini-grid and large-scale market segments for wind and solar PV in Kenya. Section 2.5 then describes each of the four disaggregated sectoral innovation systems and their characteristics, drawing on the dynamics presented in Section 2.4. Section

2.6 discusses the similarities and differences across these sectors using the three main dimensions of the SIS approach as vectors. Finally, Section 2.7 pulls together the key findings of the research and provides a discussion of how the disaggregated SIS analysis can highlight the coexistence of different innovation systems within broadly defined sectors. It sums up by drawing insights for policymakers and future research on shaping electrification pathways in countries where the process of electrification is ongoing. Our findings have wider significance because the size and shape of these pathways add-up as defining features of alternative electrification paradigms.

2.2. DISAGGREGATING THE INNOVATION SYSTEMS APPROACH

Innovation systems approaches are increasingly used for the analysis of development problems, including development problems in Africa (Lundvall & Lema, 2014; Adebowale, Diyamett, Lema & Oyelaran-Oyeyinka, 2014). The sectoral systems perspective ascribes importance to learning, knowledge and capability accumulation in the innovation process (Malerba, 2005). The SIS perspective is based on the underlying assumption that innovation dynamics are closely related to the specific characteristics of a given sector or industry. Innovation within a sector is a dynamic process, which constantly transforms the structure and boundaries of a given industry. In this paper, the focus is on analysing two low carbon technologies, namely solar PV and wind technologies in Kenya.

While there are profound differences between low carbon technologies (Lema, Iizuka & Walz, 2015), the differences within solar PV and wind energy overarching technological categories are equally profound. To give an example, the notion of a ‘solar technology' may be used as an umbrella term to describe solar-powered LED lamps, solar home systems and utility-scale solar power plants. Common to these systems is the fact that they make use of solar panels as the underlying source of electricity generation. However, it is clear that there are significant differences between the respective users, producers, investors, actors, prices, scales, R&D intensities, value chains, technical characteristics and competing technologies of these systems (Adebowale et al., 2014). As noted by Stephan et al. (2017), understanding such differences in sectoral configurations helps identify dynamics that otherwise go unnoticed. As a result, each of the subcategories of these systems of technology may more appropriately be considered units of analysis in their own right. In the delineation of specific sectors, a key question therefore concerns the selection of an appropriate level of aggregation in the analysis. Accordingly, the case of solar and wind technologies examined in this paper are understood as subsectors of the wider renewable energy sector, which in turn is considered a subset of the broader energy sector, and so forth. Initially, Malerba defined SISs broadly as “a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products” (Malerba, 2002). While this broad definition was developed with the intention to be able to cover research conducted at various level of aggregation, most empirical studies in this field focuses on a highly aggregated level of analysis covering the entire pharmaceutical, chemical, telecommunications or biotechnology sectors (Malerba, 2005)]. In this paper, we adopt a more disaggregated level of analysis in order to uncover in further detail the innovation dynamics within such overarching and broadly defined sectors.

Based on this understanding of technology, this paper distinguishes between small-scale mini-grids and large-scale power plants using solar and wind technologies to generate electricity. Mini-grids are understood as decentralised (off-grid) systems consisting of power-generating assets and distribution with power capacities of between 0.2 kW and 2 MW connecting two or more individual households (Pedersen, 2016). Large-scale power plants are understood as grid-connected plants owned by utilities and/or private operators with installed capacities above 15 MW.

The above description translates into the conceptualisation of four different SISs in Kenya with distinctive sector-specific innovation features, which are explored in the paper: (i) wind-powered mini-grids; (ii) large-scale, grid-connected wind-power plants; (iii) solar-powered mini-grids; and (iv) large-scale, grid-connected solar power plants. Following the SIS perspective, three main dimensions are used to guide the analysis of these four sectors (Malerba, 2011):

- Knowledge and technologies
- Actors and networks
- Institutions

The knowledge and technology dimension focuses on the underlying knowledge bases of a given sector, which can be highly unique to the sector as a result of the interactions between the firms and organisations involved. The knowledge base in some sectors relies mainly on tacit know-how, craft and practical skills, while others depend more on codified knowledge and formal R&D (Asheim & Coenen, 2005; Pavitt, 1984). This means that knowledge created within specific sectors may not be easily acquired and transferred across sectors.

The actors and networks within SIS may involve firms as well as non-firm actors and their mutual interaction in the dynamic learning and innovation processes within specific sectors. While firms play an important role, governments, universities, suppliers, financial institutions and NGOs are examples of other actors that take part in the in-novation activities of a given sector (Malerba, 2011).

The institutions of a given sector involve the surrounding infrastructure and enabling framework conditions in which innovation takes place. Such institutions can be more or less formal, ranging from laws, regulations and standards as formal, tangible institutions to norms, habits and routines as informal institutions resulting from repeated interactions among actors. These institutional conditions shape the involvement and interactions of actors and influence the learning processes that lead to the accumulation of knowledge and capabilities (Malerba, 2005).

Using the SIS approach as an analytical framework also prompts bigger questions as to its strengths and drawbacks. As noted by Kern (2015), one criticism of the innovation systems approach is the apolitical nature of its analyses, and while some aspects of politics may be covered by, for example, the institutional dimension of the framework used in this paper, others view the politics as pervasive across all the dimensions and functions of innovation systems. Although an explicit analysis of the agents of change that may reveal the relative differences and similarities of the four sectors is not included, the framework does explore the drivers and barriers for each sector. Revealing the differences and similarities of the dynamics across sectors makes possible a discussion of how policymakers and stakeholders can take more informed decisions regarding how to nurture renewable energies across complementary sub-sectors. It is im-portant to note here that the under- or over-prioritisation of certain sectors in relation to others is not simply based on technical decisions, but essentially involves political choices and prioritizations. Large-scale solar and wind-energy projects are essentially large infrastructure projects that are typically highly political in nature and that involve a multitude of actors with competing interests and negotiations across various levels. For example, some argue that the push for RE in Kenya is not necessarily being driven by environmental concerns, but rather by the need to provide access to electricity to the highest number of people within the shortest time possible (Newell, Phillips, Pueyo, Kirumba, Ozor & Urama, 2014). These authors highlight the tensions that come from pursuing the multiple objectives of ‘growth’, ‘inclusiveness’ and ‘sustainability’ (Lema, Johnson, Andersen, Lundvall & Chaudhary, 2014). Few studies have addressed the political economies of the RE sector in Kenya with the exception of Newell and Phillips, who look at transitions in the energy sector more broadly (Newell & Phillips, 2016).[8] By unpacking the innovation dynamics at a more disaggregated level, this study makes possible future research to facilitate a focus on the political reasons for the relative differences, strengths and weaknesses of the renewable energy sector.

2.3. RESEARCH METHODS

This article seeks to bring together results from research conducted as part of a wider project on renewable electrification in Kenya entitled Innovation and Renewable Electrification in Kenya (IREK), which examines the implementation of wind and solar technologies in Kenya’s renewable electrification process (IREK, n.a.). This article distils insights from reports produced for the project which also include further detailed information on each of the sub-sectors (Hansen, 2017; Tigabu, Kingiri,

[8] See also Ahlborg (2017)

Odongo, Andersen & Lema, 2017) as well as on ongoing research work by the five authors.

The main source of information for Sections 2.4 and 2.5 of this chapter was semi-structured interviews with key actors involved in the sectoral systems. Information derives mainly from interviews carried out in Nairobi in 2016 and 2017. Actors and organisations interviewed include project developers, regulators, investors, plant operators, technology suppliers, donor agencies and government agencies. Interviews were conducted using predeveloped interview guides with predefined questions tailored to the specific interviewees in question. The data was analysed by operationalising the three main features of the SIS perspective described above to capture the innovation dynamics within the RE sector in Kenya. Data collected in interview were compiled into the three main categories of the SIS perspective across the four sub-sectors, using the tabular approach suggested by Miles and Huberman (1994). The subsequent analysis focused on condensing and distilling the main findings within each of the four sub-sectors

To gain an overview of the market status and trends and to triangulate information, desk research has reviewed and consulted a large variety of documents, including papers from the peer-reviewed literature, media reports, presentations, company press releases, and industry and other reports. Data collected from documentary sources used a similar approach by identifying events (e.g. project or policies) addressing the SIS dynamics across the four sub-sectors.

2.4. SOLAR PV AND WIND MARKET STATUS AND TRENDS IN KENYA

The following sections will report on the status of market development in Kenya across the mini-grid and large-scale market segments for wind and solar PV technologies respectively, following the structure shown in Table 2-1. As seen the different technology domains made up of various shapes and sizes, relate wider pathway dimensions regarding the deployment trajectories evolving in either distributed mini-grids or grid-connected projects.

Table 2-1 Technology system sub-categories of wind and solar PV

	Wind	**Solar**
Small	Wind-powered mini-grids (section 2.4.1)	Solar-powered mini-grids (section 2.4.3)
Large	Grid-connected wind-power plants (section 2.4.2)	Grid-connected solar-power plants (section 2.4.4)

2.4.1. WIND-POWERED MINI-GRIDS

The wind-powered mini-grid market segment in Kenya includes a mixture of state-owned mini-grid power stations and commercially operated mini-grids. As the information available regarding these facilities is generally scarce, the following overview has been assembled from a variety of sources from the period 2013–2016.

According to these sources, there were 21 state-owned mini-grid stations in Kenya in 2016. The majority are owned by the Rural Electrification Authority (REA) and operated by the Kenya Power and Lighting Company (KPLC), while two are operated by the Kenya Electricity Generating Company (KenGen) (ESMAP, 2016). The mini-grids include diesel-fired generators and combined hybrids with solar and wind. The two wind hybrid plants are operated by KPLC and include the diesel–wind hybrid plant in Marsabit (500 kW) and a solar–wind–diesel hybrid plant in Habaswein (50 kW), with a combined total installed wind-power capacity of 0.55 MW (Table 2-3) (GoK, 2011).

Table 2-2 Mini-grids owned and operated by KPLC in Kenya in 2015

Mini-grid	Type	Nominal capacity (kW)	Effective capacity (kW)	Customers
Baragoi	Diesel	248	138	230
Eldas	Diesel	184	184	80
Elwak	Hybrid Solar	740	610	802
Habaswein	Hybrid Solar & Wind	760	542	1,015
Hola	Hybrid Solar	1,220	660	1,956
Lodwar	Hybrid Solar	2,740	1,480	2,380
Lokichoggio	Diesel	680	500	166
Mandera	Hybrid Solar	2,350	1,480	4,000
Marsabit	Hybrid Wind	2,900	2,800	3,300
Merti	Hybrid Solar	250	170	436
Mfangano	Hybrid Solar	520	390	120
Mpeketoni	Diesel	1,285	950	1,503
Rhamu	Diesel	184	184	2,132
Takaba	Hybrid Solar	244	244	300
Wajir	Diesel	3,400	3,130	4,100
Total		17,705	13,462	20,598

Source: Carbon Africa Limited (2015).

A number of companies also offer wind and solar-powered mini-grids to villages and households on a commercial basis. Anecdotal evidence of the scale of this market varies from at least a dozen wind/solar/micro-hydro/hybrid mini-grids to eighty to a hundred small wind turbines (400 W), often installed as part of a solar PV–wind hybrid system with battery storage (Pedersen, 2016; GIZ, 2009). These have been installed by telecoms players, NGOs and both commercial and household clients. Private companies operating in Kenya with expertise and activities in wind-powered mini-grids include PowerGen, Wind for Prosperity Kenya, CraftSkills, WinAfrique, Chloride Exide, and Davis and Shirtliff(AHK, 2013; Carbon Africa Limited, 2015).

Table 2-3 Key characteristics of the two existing wind-powered mini-grids in Kenya

	Marsabit	Habaswein
Installed wind capacity	Two 250 kW wind turbines	Three 20 kW wind turbines
Total system supplier	Socabelec East Africa Ltd.	-
Turbine supplier	Vergnet Groupe (France)	Layer Electronics S.R.L (Italy)
Key component supplier	ABB PowerStore system (500 kW)	-
Start date of operation	Scheduled for completion in 2016	-

Source: authors' own elaboration

There are references to the use of small-scale wind energy for water pumping in Kenya going back to the early twentieth century, and by 2005 about 300–450 wind-powered water pumps were estimated to be in operation (Kamp & Vanheule, 2015). With respect to electricity-producing wind turbines, one local Kenyan manufacturer has been active since the late 1990s, and three foreign manufacturers started activities in 2010–2011 by installing a small number of wind turbines. From around 2011, however, domestic wind turbine suppliers have increasingly shifted their focus and activities toward the emerging market for solar-powered mini-grids, as in the case of the companies RIWIK and SteamaCo. To explain this shift, AHK [24] referred to the limited size of the domestic market for wind turbines compared to the emerging market for solar PV (across market segments), while other interviewees mentioned the decrease in the price of solar panels and their relative ease of installation and maintenance compared to wind turbines. Kamp and Vanheule (2015) estimate that around twenty companies currently offer imported wind turbines, but they are predominantly installers of solar PV systems that complement their energy product portfolio with wind turbines. Locally produced wind turbines are typically in the range of 150 W–3 kW, and between 120 and 150 wind turbines within this range have been in-stalled in Kenya to date (Vanheule, 2012). The typical size of commercial solar-powered mini-grid systems currently offered by domestic suppliers in Kenya is in the range of 15–100 kW. Given their lower capacity level, the locally produced wind turbines are smaller and not well-suited to catering to this market. Imported turbines are in the range of 1–5 kW, and their average efficiency, reliability and price are generally higher than those of locally produced wind turbines.[9] According to Kamp and Vanheule (2015), an increasing number of local manufacturers are offering imported turbines from China, but detailed information about Chinese wind turbines installed in Kenya is thus far limited.

A number of new wind-powered mini-grids are being developed. AHK (2013) listed five new wind–diesel hybrid mini-grids currently under construction in Kenya with a total capacity of 600 kW. The Kenyan government's rural electrification master plan from 2009 also included support for the retrofitting of existing diesel-based decentralised power stations into hybrid schemes with wind and solar PV(REA, 2009). As part of the implementation of the master plan, 44 new sites are planned for development as hybrid mini-grids, including nineteen wind turbines with a total capacity of 1.9 MW (AHK, 2013). The development of mini-grids in Kenya is supported by various donor organisations, such as the World Bank's Scaling-up Renewable Energy Program (SREP), which aims to install 3 MW of wind and solar hybridized with the existing diesel generators in twelve isolated grids with a total installed capacity of 11 MW (GoK, 2011). Similarly, the Department for International Development (DfID) and the German Corporation for International Cooperation (GIZ) provide various kinds of support for the hybridization of existing diesel-fired mini-grids with wind or solar PV and the development of private mini-grids. However, none of these organisations appear to have an explicit focus on wind-powered mini-grids, and they mainly concentrate on supporting the development of solar-powered mini-grids.[10] One notable exception is the UNIDO-funded project in the Ngong Hills implemented in 2009, which involves a solar–wind–diesel hybrid mini-grid with a total installed capacity of 10 kW (including a 3 kW wind turbine) (Gollwitzer, Ockwell, Muok, Ely & Ahlborg, 2018).

2.4.2. LARGE-SCALE, GRID-CONNECTED WIND-POWER PROJECTS

At present there is only one operational, large-scale, grid-connected power project in Kenya: the 25.5 MW Ngong Power Station, which comprises six 850 kW Vestas turbines and 24 Gamesa 850 kW turbines. The plant is owned by KenGen and was established in 1993 with two turbines donated by the Belgian government. Four additional large-scale wind-power projects are currently under development in Kenya, including the prominent Lake Turkana project (310 MW), the Kipeto Energy Wind Park (100 MW), the Kinangop Wind Park (60 MW), which has recently been

[9] The price of small-scale wind turbines (150 W-300 W) sold in Kenya is around KES 100.000-200.000, while the price range of turbines of around 1 kW are KES 280.000-350.000 and can reach up to KES 800.000 for larger turbines (of 3 kW) (Vanheule, 2012)

[10] See, for example, the recent announcement by the French development agency to "support the installation of RE generation units (primarily solar photovoltaic (PV), but also in some cases wind turbines in 23 mini-grids currently powered by diesel generators" (ESI Africa, 2018)

cancelled at a late stage in its project development, and the Baharini Electra Wind Farm project (90 MW).

The largest and most advanced project is the Lake Turkana Wind Power project, which has been developed by a consortium of international actors, including the Danish Investment Fund for Developing Countries, Vestas, the Finnish Fund for Industrial Cooperation and KLP Norfund Investments. The project is located in the area around Lake Turkana in northern Kenya and involves the installation of 365 (850 kW) Vestas turbines, which are imported from China (AHK, 2013). It is often mentioned as the largest wind-power project in sub-Saharan Africa and will add what corresponds to approximately 15% of total installed electricity generating capacity in Kenya. Although the power purchasing agreement (PPA) had already been signed with KPLC in 2010, the construction of the wind turbine park was completed in early 2017. However, delays in the construction of the transmission line to connect the project to the national grid have led to uncertainty regarding the project's exact commissioning date.

A consortium consisting of the African Infrastructure Investment Fund, Craftskills Wind Energy International Ltd., the International Finance Corporation and the Kipeto Local Community Trust own the Kipeto Energy Wind Park. In 2015, the consortium signed a PPA with KPLC, and at the beginning of 2016 the Chinese company, China Machinery Engineering Corp., was contracted as the EPC contractor.[11] The project will include the installation of sixty turbines supplied by General Electric. According to the ERC (2015), however, the PPA has not yet been agreed and is still undergoing evaluation.

The African Infrastructure Investment Fund II and Norfund originally provided the funding for the Kinangop Wind Park project with debt finance supplied by the Standard Bank of South Africa. The project was planned to have been completed in 2015, with 38 turbines supplied by General Electric and Iberdrola as the EPC contractor in cooperation with the Kenyan-based consultancy company Aeolus Kenya Ltd. The project experienced delays and was eventually cancelled in early 2016 [29]. A number of media reports have claimed that the cancellation of the project was mainly due to local opposition relating to land rights issues (Kamadi, 2018: McGovern, 2018; Eberhard, Gratwick, Morella & Antmann, 2016).

The Baharini Electra Wind Farm project is financed by the World Bank's International Finance Corporation and will be carried out by Belgian Electrawind in collaboration with local partner Kenwind (ESI Africa, 2016). It seems that the project has not

[11] Engineering, procurement and construction (EPC) contracts are a prominent form of contractual agreement in the construction industry. The EPC contractor carries out the detailed engineering design for the project, procures all the equipment and materials necessary, and then undertakes the construction in order to deliver a functioning facility or asset to its clients.

advanced beyond the initial feasibility and planning stage. This means that financial closure and a PPA have not yet been agreed and that technology suppliers and contractors have not been identified.

The above projects are being developed in connection with the Kenyan feed-in tariff for wind-power projects, which was first introduced in 2008 and later revised in 2012. The current tariff offered for wind-power projects in the range 50–100 MW is US$ 0.11/kWh (WinDForce, 2013). The feed-in tariff for wind-power projects has attracted interest from a number of private developers, donors and development banks, which have provided financial support and advisory services to move the project toward reaching financial closure (Eberhard et al., 2016). This has resulted in a high number of applications submitted under the FIT. WinDForce (2013) reports that by 2013 a total of 236 applications had been sub-mitted under the FIT system, of which twenty had been approved. However, as none of these projects has signed a PPA or progressed to full operation, it appears that movement on the ground has been slow. The Lake Turkana project provides an illustrative example, reaching financial closure nine years after it had begun.

2.4.3. SOLAR-POWERED MINI-GRIDS

Eight state-owned solar-powered mini-grid stations are currently in operation in Kenya, including seven solar–diesel hybrids and the wind–solar–diesel hybrid mentioned previously (see Table 2-2). The total installed capacity of these solar-powered mini-grids, which are owned by REA and operated by KPLC, is 0.51 MW (see Tables 2-4 and 2-5 below)(Gichungi, 2014). More detailed information on these state-owned, solar-powered mini-grids in Kenya is generally scarce. However, in general, European companies specialising in the supply of core solar technology components to mini-grids and related engineering and consultancy services are strongly represented in Kenya, especially companies from Germany. Examples of German-based companies supplying such components, which include panels/modules, inverters, controllers and batteries, include Energiebau Solarstromsysteme, Donauer Solartechnik and Juwi AG. These foreign companies are typically closely linked to local project developer companies in Kenya, such as Harmonic Systems Ltd., Dreampower (local subsidiary of an Italian company) and Solar Works Ltd. in the development of different projects.

Table 2-4 Key characteristics of the Mfangano solar-powered mini-grid

Installed solar capacity	40 kWp (no battery)
Total system supplier (EPC)	Dreampower and Juwi AG
Commissioning	2013
Core components	N/A

Source: (Dinnewell, 2014).

Table 2-5 Installed capacities of wind and solar in existing mini-grids in Kenya

No.	Station	County	Installed capacity (kW)		
			Diesel	Wind	Solar PV
1	Wajir	Wajir	1746	0	0
2	Mandera	Mandera	1600	0	300
3	Marsabit	Marsabit	560	500	0
4	Lodwar	Turkana	1440	0	60
5	Hola	Tana River	800	0	60
6	Merti	Isiolo	128	0	10
7	Habaswein	Wajir	360	50	30
8	Elwak	Mandera	360	0	50
9	Baragoi	Samburu	128	0	0
10	Mfangano	Homabay	584	0	0
Total			**7706**	**550**	**510**

Source: (Gichungi, 2011; RECP, 2013).

The existing solar PV industry in Kenya includes one local assembly plant entitled Ubbink East Africa Ltd., which supplies solar PV panels with capacities between 13 and 240 Wp (the bulk of sales are of 40 Wp modules) and a number of local battery producers/suppliers, such as Chloride Exide Ltd. (Byrne, 2011; Ockwell & Byrne, 2016). However, it appears that the local industry is mainly focused on serving the Kenyan market for domestic solar systems and smaller scale solar applications for individual households (Hansen, Pedersen & Nygaard, 2015). It seems evident, therefore, that most of the core system components in the solar-powered mini-grids in Kenya are imported from abroad, typically from renowned European or American companies through local sales offices and wholesale retailers (AHK, 2013).

A further fifteen state-owned, solar-powered mini-grids are currently under construction in Kenya with a total capacity of 2 MW (AHK, 2013). A further nine solar-powered mini-grids with a total capacity of 1.8 MW are being developed as hybrid solar–diesel mini-grids (in existing diesel-fired plants), and an additional 25 plants (with a total capacity of 5.6 MW) are at the initial proposal stage. Most recently, REA has announced a call for tenders for the development of 25 new solar-powered mini-grids (REA, 2016). Donor organisations also actively promote the development of solar-powered mini-grids in Kenya by providing financial support to specific projects, such as the development of up to 26 new solar-powered mini-grids (mainly solar–diesel hybrids) by the KfW Development Bank and GIZ through the German development agency (ESMAP, 2016). Similarly, DfID and the World Bank have provided direct investments for the development of new (greenfield) solar-powered mini-grids, including the recently launched Kenya Off-grid Solar Access Project (KOSAP) (World Bank, 2018), while the Spanish embassy has provided financing for the development of five new solar–wind–diesel hybrid mini-grids. Other donor-funded projects include the DfID-funded co-operative-based Kitonyoni mini-grid (a solar–diesel hybrid of 13.5 kWp), the UNIDO-funded, community-based Olosho Oibor mini-grid (a solar–wind–diesel hybrid of 10 kWp) and two solar-diesel hybrid mini-grids funded by GIZ: the Talek Power mini-grid (50 kWp) and the Strathmore University solar hybrid system (10 kWp) (Pedersen, 2016; Gollwitzwer et al. 2018; Gollwitzer, 2016).

A number of private companies are involved in supplying solar-powered mini-grids on a commercial basis in Kenya, which include Powerhive East Africa Ltd., PowerGen and Talek[12] (Carbon Africa Limited, 2015). Since 2012, these foreign-owned companies have installed between twenty and thirty solar-powered mini-grids with a capacity of 1.4–10 kW with a few examples of larger systems (20 and 50 kW). Two of these companies have received a formal license to operate, and one has secured financing to establish a portfolio of another hundred mini-grids (Pedersen, 2016; Harrington, 2016). These companies have had initial pilot phases and are now in the process of significantly upscaling their activities in Kenya (Earley, 2017). Most of the core components used in these solar-powered mini-grids are sourced from renowned suppliers from Europe or the US either in-house or through external suppliers. It should be noted that SteamaCo has developed a smart metering system, which has been installed in a number of solar-powered mini-grids in Kenya along with related soft-ware services.

2.4.4. LARGE-SCALE, GRID-CONNECTED SOLAR-POWER PROJECTS

Currently, there are five grid-connected solar power plants in operation in Kenya. These include: (i) a 575 kWp plant installed at the UN compound in Nairobi; (ii) a plant at the SOS Children's Village in Nairobi (60 kWp); (iii) a 100 kWp plant installed at Kenyatta University; (iv) a 72 kWp system installed at a flower farm; and (v) a 1 MWp plant at a tea-processing facility (AHK, 2013; Hansen, Pedersen & Nygaard, 2015). While the first three plants were financed mainly by international donors, the latter two were financed by the owners of the industrial plant. The existing plants appear to have been delivered on a turnkey basis by total system suppliers from abroad in cooperation with local consultancy companies and installation contractors (Dinnewell, 2014). For example, the German company Energiebau Solarstromsysteme GmbH was the turnkey provider of the first-mentioned plant in cooperation with the Kenyan-based company SolarWorks, which included the sourcing of all of the core components, mainly from European suppliers (modules from Schott Solar and Ka-neka, and inverters from SMA Solar Systems) (AHK, 2013; Hille & Franz, 2011). Similarly, the second plant was constructed by the UK-based company Arun Construction Services in cooperation with the local company Azimuth

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[12] The Talek power company has been created as a so-called 'special purpose vehicle' by the German development agency GIZ and has been set up as a private company in trust (GIZ, 2015; ESMAP, 2016)

Power (modules from Centrosolar AG and inverters from SMA Solar Systems) (Hille & Franz, 2011). In the fifth plant, the tea-farm owner commissioned the UK-based company SolarCentury to deliver the plant, including imports of key components, in cooperation with the Kenyan-based companies East African Solar Ltd. and Azimuth Power (SolarCentury, 2017). An additional plant at Strathmore University (0.6 MW), which signed a PPA in 2015 has recently been commissioned and is currently in operation. In this project, the Kenyan companies Questworks and ReSol have been contracted as the total system provider and installation contractor respectively, and key components will be sourced from European and Chinese suppliers (including panels from JinkoSolar and inverters from Solaredge). In general, the involvement of additional local companies in the above-mentioned plants seems to be limited mainly to local technicians and engineers during the construction stage, as well as local contractors of maintenance services during operation.

Table 2-6 ERC approved projects to be developed under feed-in tariff system (2015)[13]

Technology	No. of applications	Capacity (MW)		Percentage
		Proposed	Approved	
Wind	1	50.00	50.00	11.80
Hydro	0	0.00	0.00	0.00
Small Hydro	13	85.95	85.95	20.30
Geothermal	0	0.00	0.00	0.00
Solar	3	120.00	120.00	28.40
Biogas	6	167.30	167.30	39.50
Co-generation	0	0.00	0.00	0.00
Total	**23**	**423.25**	**423.25**	**100.00**

Source: (ERC, 2015).

A number of projects on a significantly larger scale seem to be under development in Kenya as part of the feed-in tariff (FiT) system, which currently offers a tariff of US$ 0.12/kWh for project developers (ERC, 2015) (see Table 2-6). This includes the Samburu project (40 MW), the Garissa project (50 MW), the Greenmillenia Energy project (40 MW), the Nakuru project (50 MW), the Kopere Solar Park project (17 MW), the Witu Solar Power project (40 MW) and the Alten Kenya Solarfarm project (40 MW) (Hansen, Pedersen & Nygaard, 2015; Tigabu, 2016). These projects are being developed by foreign technology suppliers and companies specialised in large EPC contracts in the energy sector, such as Stimaken and Martifier Solar. Common to these planned projects is that none of them appears to have advanced from the stages of initial expressions of interest and feasibility studies to reach financial closure and

[13] The list includes projects for which expressions of interest have been approved by the FiT evaluation committee. In the three previous annual reports prepared by the ERC, the number of solar projects listed as 'approved solar PV projects' were 20, 16 and 9 respectively, indicating that since 2012/13, 48 solar power projects have been approved under the FiT, none of which have been realized or have a signed PPA as yet

the signing of PPAs. It appears that the various project developers are generally struggling to secure funding and reach financial closure (Eberhard et al., 2016; Dinnewell, 2014). Hence, as project planning and preparation for most of these projects had started already in 2012, movement on the ground seems relatively slow, and most of these projects have not yet reached the construction or operational stages (ERC, 2015; Eberhard et al., 2016). A number of donors and development banks, such as the World Bank and the German development agency, support most of these projects.

2.4.5. SUMMARY OF SOLAR AND WIND MARKET TRENDS AND STATUS

Looking at the overall wind sector, there is clear variation in the dynamics of small- and large-scale wind. The market for small-scale wind-based mini-grids appears to have stalled: very few hybrids exist or are planned, and private suppliers of wind-powered mini-grids have shifted focus. In contrast, the market for large-scale wind projects is moving forward, with the flagship Lake Turkana project drawing massive attention, together with a number of other large-scale projects.

In the overall solar sector, the market for small-scale solar-based mini-grids is currently experiencing a period of significant momentum, with both private mini-grid operators and many donors involved with existing and planned hybrid greenfield mini-grids (Duby & Engelmeier, 2017). On the other hand, the market for large-scale solar projects has only moved to a very limited extent on the ground, as existing projects are small in scale, and large-scale projects remain at the planning stage. In the next section, these trends will be compared to the characteristics of the four disaggregated SISs.

2.5. THE SIZE AND SHAPE OF WIND AND SOLAR SECTORAL INNOVATION SYSTEMS

In the following sections, the characteristics of the four SISs are explored and disentangled. The SIS perspective is used to describe the three dimensions – knowledge base, actors and institutions – of the wind and solar sectors across the size and shape of the projects. Based on the market trends presented above, the following descriptions of the system characteristics aid the discussion of the potential differences in the relative strength of the four SISs in respect of generating and diffusing solar PV and wind technologies in Kenya.

2.5.1. SECTORAL INNOVATION SYSTEM CHARACTERISTICS OF WIND-POWERED MINI-GRIDS

The existing knowledge and technological base in the domestic industry for wind turbines in Kenya is characterised by relatively simple and small-scale technologies manufactured locally. Such small-scale systems can be tailored to different local contexts and manufactured from a range of locally available materials while still being relatively robust. As the turbines are typically produced by smaller manufacturers, universities or NGOs involved in community projects, they do not require advanced engineering knowledge or skills. Thus, as opposed to formalized R&D, the domestic industry for small-scale wind turbines is generally characterised by a high level of informal knowledge and learning in the way that local artisans and blacksmiths tinker with various designs based on the available equipment and materials. While the wind turbines are produced and diffused at relatively low cost, final performance and standards tend to vary greatly. The locally produced systems are contrasted with the imported turbines used in the existing wind–diesel hybrid mini-grids, which are generally higher in performance and price levels (Vanheule, 2012). Due to the lack of experimentation with wind-powered mini-grids, related technical concepts and commercial applications, limited specialisation and experience has been accumulated in this area. The main supportive institutional conditions promoting the development of wind-powered mini-grids are related to initiatives adopted as part of the rural electrification master plan to hybridize the existing diesel-fired mini-grids with wind and solar (REA, 2009). These initiatives are supported and complemented by various donor programs but are also driven by the increasing operational costs of the existing diesel-fired mini-grids. The main actors involved in the domestic industry are local wind turbine manufacturers, NGOs and local community entrepreneurs involved in various small-scale projects typically implemented by donors in rural villages (Harries, 1997; Bergès, 2009). A number of these projects include individual engineers and NGOs from abroad in-volved in testing a specific technical design for rural applications (Ferrer-Martí, Garwood, Chiroque, Ramirez, Marcelo, Garfì & Velo, 2012). The local manufacturers rely on local supply chains and distribution networks and typically make use of connections in the local environment for sourcing materials and related know-how. Government agencies promoting rural electrification in off-grid areas are typically also involved in specific projects either directly or indirectly via technical support. The Ministry of Energy and Petroleum is also involved in the installation of wind speed data loggers at 20 m and 40 m. Local universities sometimes provide highly applied research input to specific projects such as a collaboration between Jomo Kenyatta University of Agriculture and Technology and the Japanese Government on small wind technology, but formalized R&D activities at universities focusing specifically on small scale wind is largely absent in Kenya.

2.5.2. SECTORAL INNOVATION SYSTEM CHARACTERISTICS OF LARGE-SCALE, GRID-CONNECTED WIND POWER PROJECTS

The knowledge and technology base underlying the development of advanced large-scale wind turbines has evolved into a highly researched and capital-intensive process involving the continuous development of new materials, designs and production methods. Thus, the development of utility-scale wind turbines involves both internal

R&D carried out within industry lead firms and formalized R&D undertaken by research centers at universities or public research organisations. These R&D activities mainly draw on technical disciplines and engineering-based knowledge. The ongoing development efforts focus on improving the price and performance of wind turbines in order to increase the competitiveness of wind power compared to conventional sources of energy for power generation. As economic feasibility generally increases with the size of the wind turbines, the general trend in the industry has been towards the gradually increasing scale of wind turbines. The development of large-scale wind-power projects also draws on a broader set of organizational and administrative competences, including the skills and systems for turbine component manufacturing (e.g. supply chain management) and the knowledge required for EPC contracting and the incorporation of third-party consultants (legal advice and engineering consultancy). In the projects under development in Kenya, the main contractors and wind-turbine suppliers have drawn upon a range of such knowledge bases and areas of expertise during project development. International actors, such as pension funds, development banks, donors and other types of financial institutions, play an important role in providing finance for the development of the projects. Due to the high national relevance of the projects as large infrastructure investments, national policymakers, regulatory bodies and government agencies are also involved in developing them. The government support for large-scale wind (and solar) is part of a broader objective to attract foreign investment in Kenya by making possible the inclusion of private, independent power producers (IPPs) in the energy sector. While direct involvement includes bilateral negotiations between project developers and the relevant authorities, indirect involvement includes political advocacy influencing the projects. While not being directly involved, local community and actor groups exert a strong indirect influence on project development, mainly due to disagreements over land rights issues. The main supporting instrument promoting the development of large-scale wind-power plants in Kenya is the feed-in tariff, which applies to projects with a capacity over 50 MW.

2.5.3. SECTORAL INNOVATION SYSTEM CHARACTERISTICS OF SOLAR-POWERED MINI-GRIDS

The knowledge base underlying the development of solar-powered mini-grids in Kenya draws on a variety of disciplines and relies particularly on foreign expertise. In the case of the state-owned solar–diesel hybrids, the main expertise needed is in the area of turnkey contracting. The necessary technological skills of the total system suppliers relate mainly to the capacity to design the plants, manage the sourcing of key components and undertake the construction and final commissioning of the plants. Since this expertise is not currently available from domestic suppliers in Kenya, European companies with significant experience in turnkey contracting and related engineering tasks dominate the development of these plants. Despite the technical capacity and knowledge accumulated in the domestic industry for solar home systems (Byrne, 2011), the local suppliers of core components (such as panels and batteries) seem disconnected from the development of solar-powered mini-grids. The private companies from abroad supplying solar-powered mini-grids on a commercial basis in Kenya draw mainly on engineering-based knowledge in the ongoing technical experimentation efforts to optimize their mini-grid systems. Experience from the telecommunications industry has also provided input into the development of a business models based on pay-as-you-go (PAYG) systems specifically developed to target poor customers in rural, off-grid areas. This business model draws on knowledge about IT and software solutions and related data analysis and optimization systems, as well as the use of smart metering and monitoring technologies. Some of these companies are engaged in client relations with (private) investors in solar-powered mini-grids, some of which are philanthropic foreign investors (Harrington, 2016). Collaborative networks have been established across a number of these companies, as well as linkages to foreign investors, headquarters and component suppliers in Europe and the US. A number of state and donor-funded programs to hybridize the existing diesel-fired mini-grids are greatly influencing the enabling environment for the development of solar-powered mini-grids in Kenya. However, the existing regulatory frame-work for rural electrification, which focuses on conventional grid- extension programs, continues to play an important role in the development of commercial solar-powered mini-grids, resulting in lengthy approval and negotiating processes for project developers.[14] Challenges faced by many solar mini-grid developers still often include access to finance or ensuring affordability of the projects as the higher cost of such small-scale energy production is borne by the consumers. The lack of focus on such new models for producing and distributing energy is also visible in the policy frameworks, where grid-owners and operators have called for stronger and clearer regulation regarding tariffs, integration, standards, licensing as well as the possibility for subsidy schemes (Duby & Engelmeier, 2017).

2.5.4. SECTORAL INNOVATION SYSTEM CHARACTERISTICS OF LARGE-SCALE, GRID-CONNECTED SOLAR POWER PROJECTS

A key driver for the development of large-scale solar power plants in Kenya is the rapidly decreasing costs of solar panels. The experience of plants under development in Kenya indicates that designs for large-scale solar power plants are generally well proven globally, requiring only minor design and construction modifications to adapt them to local conditions. The knowledge and technological base underlying the development of large-scale solar power plants in Kenya thus draws greatly on foreign expertise in the delivery of plants on a turnkey basis. European companies with substantial experience in turnkey plant engineering, component sourcing and commissioning have thus delivered the existing plants in cooperation with locally based consultancy companies. Due to the larger scale of the solar power plants

[14] An example of the continued focus of the grid operator and energy planning agencies in Kenya on grid extensions to promoite enhanced access to electricity for the rural population is the so-called ‘Last Mile Connectivity Project’ (AfDB, 2018)

currently under development in Kenya, their development draws on additional knowledge of EPC contracting and the related organizational expertise to manage the development of large infrastructure projects. Consequently, international contractors and technology suppliers with the technical expertise and management skills to develop an integrated plant design and to install and operate the system effectively have been involved in planning and developing the projects, as well as providing additional competences in the area of PPA contract negotiations, the legal aspects and detailed engineering tasks. While development of the existing solar power plants has included industrial users and donors as the project owners, the larger scale solar-power plants under development incorporate direct involvement from international investors, including development banks and donor organisations. However, the development of large-scale solar is generally being prevented by the difficulties project developers face in attracting finance from foreign investors, and concerns have been raised that the feed-in tariff system may be too low to incentivise foreign investments significantly (Hansen, Pedersen & Nygaard, 2015).

2.6. DISCUSSION: SUB-SECTORAL DYNAMICS ACROSS SIZE AND SHAPE

Distinguishing sectoral innovation system features across market segments and technologies has shown that it is worth considering the similarities and differences between the size and shape of the different sub-sectors of solar PV and wind energy in Kenya. In the following sections the three dimensions of Malerba's (2005) SIS framework are examined across the four sub-sectors (see also Table 2-7).

2.6.1. DIFFERENCES AND SIMILARITIES BETWEEN KNOWLEDGE BASES

Regarding the knowledge dimension, it is clear that both within and across the four SISs, each system is characterised by individually distinct knowledge bases. In fact, as noted by Malerba (2005), it is knowledge and technology that place the issue of sectoral boundaries at the center of analysis. These differences therefore support the argument that a disaggregated sectoral analysis is necessary, perhaps particularly in respect of SIS size (Stephan et al., 2017). This is evident in that both large-scale wind and large-scale solar share some characteristics related to the size of the project, where EPC contractors and turnkey suppliers are present across the technologies. Many of the enabling aspects of this dimension are found in the intersections with the global sectoral characteristics where international actors have established themselves in the Kenyan market. This is notable because domestic actors seem disconnected, despite the technical capacity and knowledge that has been accumulated particularly in the domestic industry for solar home systems. There is little information on the involvement of local suppliers of either solar or wind components in any project. It is noteworthy, however, that across the solar and wind mini-grid sectors the knowledge base dimensions differ in terms of which actors with which knowledge bases are involved. While informal learning and knowledge characterize the wind mini-grid sector, the solar-mini grid sector features rather engineering-based knowledge, with more involvement from both private actors and international donors. The solar-powered mini-grid sector is also highly specialised, with business models and software catering to specific PAYG customer segments.

2.6.2. DIFFERENCES AND SIMILARITIES BETWEEN ACTORS

In the actor dimension, foreign industry actors play a role across large-scale wind and solar mini-grids and large-scale solar. However, in wind mini-grids there is no significant presence of foreign industry actors; rather, small-scale domestic industry actors and foreign actors such as NGOs and donors focusing on small-scale development projects are dominant. While there are universities involved in practical and hands-on applied research in scientific projects, this does not translate into organized R&D in the domestic industry, and there is a notable absence of private suppliers of wind-powered mini-grids in the sector. In the solar mini-grid sector there are a number of private suppliers, foreign investors and foreign component suppliers, as well as turnkey contractors. Across both large-scale wind and solar power projects, the role of lead firms in the global industry in the wind sector and international EPC contractors is clear.

The role of local community actors is visible in both large-scale wind projects and solar mini-grids, though there is not much evidence of community involvement in wind mini-grid projects, and in the case of large-scale solar, the users tend to be large industrial players. In large-scale wind projects, the role of national policymakers and governmental agencies has been notable through their direct negotiations with project developers over power purchasing agreements.

2.6.3. DIFFERENCES AND SIMILARITIES BETWEEN INSTITUTIONS

In terms of the institutional dimension of the SISs examined here, there are clear similarities in terms of the role of feed-in-tariffs and power purchasing agreements in the large-scale solar and wind projects, while small-scale projects in both the wind and solar sectors are influenced most clearly by state and donor support for hybridization of the existing diesel-fired mini-grids. What is noticeable, however, is that, despite the same overarching driver existing for the hybridization of mini-grids because of the increasing operational costs of diesel-driven mini-grids, the solar mini-grid segment differs markedly in terms of actors and networks and has received more attention from international donors than wind mini-grids. A number of donor programs and national plans also mainly support the development of hybrid wind-diesel mini-grids. However, compared to the support for solar-powered mini-grids, the development of wind-powered mini-grids seems to be somewhat underprioritised in these initiatives. In a number of locations, especially in the eastern and northern parts of Kenya (such as the area surrounding Lake Turkana), which have particularly favorable wind resources, the development of wind-powered mini-grids can become economically viable, although optimizing location also depends on local demand (GIZ, 2014).

Overall, the solar mini-grid market appears to have a more enabling environment that has led to the establishment of a commercial market for the sale of electricity services to rural communities. This private-sector approach to the provision of rural electrification via mini-grids seems to be unprecedented in Kenya and East Africa. Many of the active companies have been started by foreign expatriates with significant expertise in business start-ups, engineering, RE consultancy, telecommunications and donor organisations. These companies have therefore brought a high level of technical and organizational expertise and management systems into Kenya, which has been combined with knowledge on energy use and needs in local communities collected by the companies over time (Rolffs, Ockwell & Byrne, 2015). However, across both wind- and solar-powered mini-grids, the challenge remains of the lack of a regulatory framework for the development of commercial mini-grids. Bilateral negotiations between the companies and key government agencies related to obtaining operational licenses and approvals of end-user tariffs have shown to be challenging and lengthy (ESMAP, 2016). The prolonged negotiating process is partly related to the different objectives of government agencies and private operators. The commercial tariff proposed by the private companies is significantly higher than the universal tariff offered by the government through the conventional grid-extension programs to support rural electrification. The regulatory authorities are generally hesitant in accepting the inclusion of private operators that are operating with business models based on low connection fees and high usage rates. In general, one aspect of the difficulties in attracting funding for RE projects is the unclear policy signals and ongoing discussions concerning the possible introduction of new incentive structures and regulatory models. Since the feed-in tariff system was revised in 2012 to its current form, a number of alternative models, such as an auction system, competitive bidding and a net metering system for smaller grid-connected projects, have been discussed.

Table 2-7 Summary of sectoral innovation system dimensions across sectors

	Wind mini-grids	Large-scale wind	Solar mini-grids	Large-scale solar
Knowledge and technologies	• Small-scale and simple wind turbines • Informal learning and knowledge • Local craftsmen and engineers • Limited knowledge of wind-powered mini-grids • Absence of formalized R&D activities carried out at universities in small-scale wind turbines • Import of higher standard wind turbines	• Formalized R&D in large-scale wind turbines • Technical and engineering-based disciplines • Complex and capital-intensive capital goods • Experience in EPC contracting and planning of large-scale plants • Expertise in PPA contract negotiation and legal aspects • Design of project tailored to local conditions	• Engineering-based knowledge • Telecom expertise (mobile payment schemes, PAYG models) • Smart metering and monitoring systems • Data management and software optimization tools Consultancy and donor experience	• Engineering-based knowledge • Experience in turnkey contracting • Experience in EPC contracting and planning of large-scale plants • Knowledge system design integration and operation
Actors and networks	• Donors, NGOs, local manufacturers involved in small-scale development projects • Actors embedded in local and regional supply chains and distribution networks • Universities involved in practical and hands-on applied research in specific projects	• Industry lead firms, such as Vestas and General Electric • International investors, including development banks, donors and pension funds • National policy-makers and key government agencies (e.g. via direct negotiation with project developers)	• European turnkey contractors • Local engineering and consultancy firms • Private suppliers of mini-grids owned by foreign expatriates • Foreign investors (direct plant investments and equity investments)	• International EPC contractors • Technology suppliers • International investors, including development banks and donors • Industrial users

	Wind mini-grids	Large-scale wind	Solar mini-grids	Large-scale solar
	• Absence of private suppliers of wind-powered mini-grids • Importers of foreign wind turbines	• Local community groups (opposing projects)	• Foreign component suppliers • Examples of cooperatives and community-based solar mini-grids	
Institutions	• State and donor support for hybridization of existing diesel-fired mini-grids • Apparent under-prioritization compared to solar mini-grids	• Feed-in tariff for wind-power projects • Financial and advisory support from donors and development banks	• State and donor support for hybridization of existing diesel-fired mini-grids • Significant funding from foreign investors	• Feed-in tariff for wind-power projects • Financial support from donors and development banks

2.7. CONCLUDING REMARKS: BENEFITS AND DRAWBACKS OF THE SIS PERSPECTIVE

In this paper, we have aimed to analyse and understand innovation dynamics within and between various sub-sectors. Based on the SIS perspective adopted in this paper, there are not only profound differences between solar and wind technologies, but equally importantly also within these technologies. Overall, the SIS perspective shows that, in terms of the key system dimensions, there is a greater similarity between large-scale wind and solar projects (size), rather than between projects within the same technologies (shape). The large-scale projects are characterised by scientific knowledge bases (R&D), with actors with EPC experience or turnkey contracting playing a large role. The projects are capital-intensive, involve management expertise and PPA negotiations, and generally involve foreign actors in terms of both technology and expertise, as well as investments. The large-scale sectors differ from small-scale wind and solar mini-grids, which are markedly characterised by decentralised electrification efforts and are highly dependent on tariff structures and cross-subsidies. The rural electrification domain is connected to discussions about grid extensions and sees many donor-driven hybridisation efforts (particularly in solar). However, it has also revealed that there are significant differences between the institutional conditions such as regulation and policy frameworks for wind and solar mini-grids, with the solar mini-grid SIS being strengthened by a range of drivers that have led to an unprecedented private sector-driven approach. In contrast, the wind-power mini-grid projects seem to have suffered both from the comparative success of the solar mini-grid market and the apparent underprioritisation of the sector by actors otherwise engaged in the mini-grid sector.

By making such comparisons and contrasts, the SIS perspective has allowed us to explore some of the drivers and barriers of the four sub-sectors. For example, across the institutional dimension it becomes clear that the drivers or institutional incentives share more similarities in size than in shape. However, these institutional incentives do not reflect the differences across actors and knowledge bases. For example, although the institutional incentives are largely similar across the small-scale solar PV and wind sectors, the large differences in knowledge bases and actors have led to the two sectors evolving at different tempos. There is an apparent lack of actors and networks driving small-scale wind, while highly specialised foreign-owned companies have contributed to the small-scale solar sector, which has experienced significant momentum in recent years. Similarly, the knowledge bases differ markedly and connect to global trends within each of the two technologies, where globally the wind industry is focusing more on developing larger and more efficient turbines rather than small-scale turbines, while the solar industry has connected to business models that focus on smaller scale applications (e.g. PAYG models).

Using the SIS perspective has thus served the purpose of teasing out differences that may otherwise have gone unnoticed using a more aggregated sectoral approach to the emerging RE sector. While the broader definition of sectors, such as RE, or even solar PV or wind as broad sectors has been used to emphasise interdependencies, linkages and transformations, in some cases the disaggregated level highlights rather the coexistence of different innovation systems within broadly defined sectors. Within the context of rapidly emerging energy systems, we argue that the disaggregated level of analysis is particularly important in designing policy, as a broad RE policy approach should consider nuances of SIS across size and shape, particularly in countries where the process of electrification is ongoing. Such a perspective is aligned with the suggestion by Malerba that “the appropriate level of analysis in terms of agents, functions, products and agents depends on the specific research goal” (Malerba, 2002). However, a disaggregated level of analysis could be of use more broadly in research in other sectors beyond RE using the SIS perspective in order to capture in detail the innovation dynamics within specific sectors. Whereas the SIS perspective was initially developed to cater for research conducted at different levels of aggregation, most empirical studies adopt a highly aggregated focus. We therefore suggest taking the initial suggestion by Malerba (2005) to conduct research on SISs at different levels of aggregation more seriously.

We posit that such an approach is highly relevant for the analysis of pathways − or ‘directions of development’ in the energy field. Such energy pathways of course rely on the specific core technology choices that determines its ‘shape’ in terms of a given energy mix, involving different renewable energy technologies. But we argue that equally, or even more, important is the issue of ‘size’ because of the ramifications of this choice for the sustainability and inclusiveness of the pathways. This choice may be particularly relevant for the prospects of producing technologies locally, using local services for constructing facilities, and involving local labour in operation and maintenance. The size choice is at the core as a defining element of alternative renewable electrification paradigms, regardless of whether such electrification is achieved by harnessing the sun, wind or water flows. While the paper has focused on wind energy and solar PV, further research needs to address whether similar conclusions may be reached when it comes to other renewables that may also be deployed in either large scale (more centralised) or small-scale (more decentralised ways), such as hydropower.

Our conclusions have important implications for ongoing policy discussions on shaping electrification pathways. It supports the opposition to any ‘one size fits all’ policy incentive in the renewable energy sector − rather, policymakers should think about how they want to shape electrification pathways across the sizes and shapes outlined here. Tailormade policies can help shape the dynamics of each sub-sector, and stakeholders and decisionmakers should ask themselves which aspects should be enhanced? The SIS perspective highlights how innovation systems are outcomes of interaction and co-evolution of both size and shape, but also across national borders and links to global industry trends. Yet the literature has also pointed out that knowledge created in specific sectors may not be easily acquired and transferred across sectors. Therefore, attention to nurturing each of these distinct sectors, how to set appropriate tariffs and incentives, but also how to establish a broader framework of technical and procedural regulations is required. The variations across sectors and the role of foreign expertise in driving certain sub-sectors also raises questions about building up the necessary capabilities and expertise within the local market. This call for future research to investigate further the 'structure' of sectoral systems and the kinds of policy mechanisms that may influence this. Furthermore, research into how interactions between and the co-evolution of such sub-sectoral innovation systems can help policymakers understand how regulations and incentive mechanisms may influence co-existing and complementary sub-sectoral systems.

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CHAPTER 3. CHINA'S INVESTMENTS IN RENEWABLE ENERGY IN AFRICA: CREATING CO-BENEFITS OR JUST CASHING-IN?

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.

Key words: Economic co-benefits, renewable energy, investment-centred global value chains, infrastructure projects, China, Africa

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3.1. 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 down-stream energy related services, such as maintenance' (IRENA, 2013, p. 15; see also Sperling, Granoff, and Vyas, 2012).

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 sub-Saharan Africa's power sector.[15] 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 hydropower, 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

[15] As emphasised by Shen (2020) it is difficult to obtain a precise estimation regarding the size and trend of Chinese activities in the power sector in sub-Saharan Africa. This reflects a larger problem regarding data shortcomings on funding from China because China has not released a breakdown of its lending activities (Horn, Reinhart, Trebesch, & Reinhart, 2020). We discuss the available data and its limitations in Section 3.3 of the paper.

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.

3.2. 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.

3.2.1. CO-BENEFITS OF CHINESE GREEN-ENERGY PROJECTS IN SUB-SAHARAN AFRICA

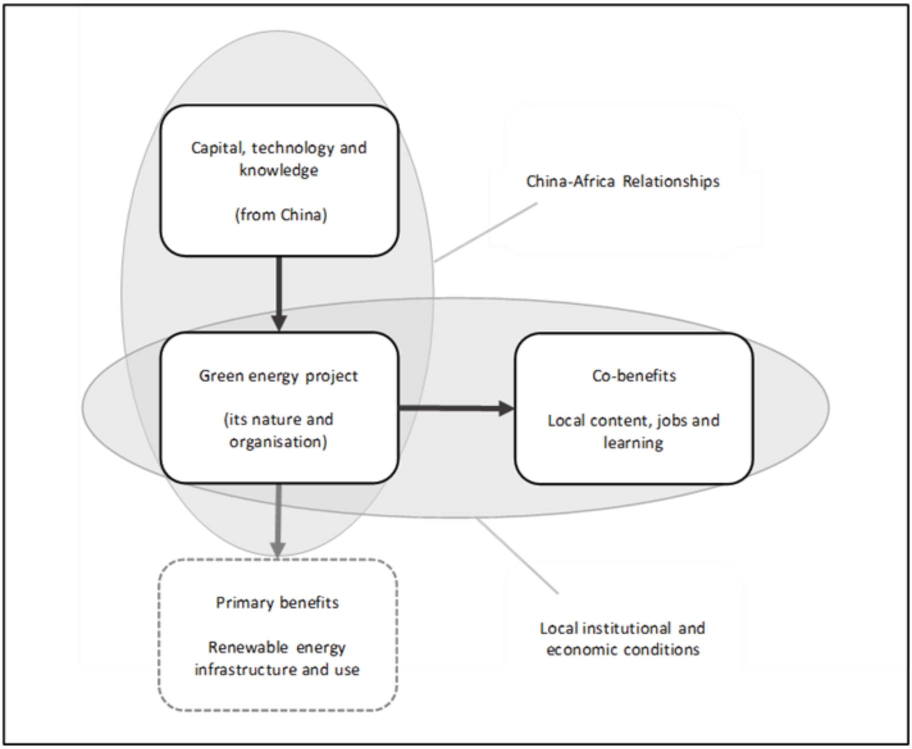
Our focus in this paper is on the concept of 'economic co-benefits' arising from Chinese renewable-energy investment projects in electricity in sub-Saharan Africa. These are the additional benefits that can potentially accompany the green-energy transition (Wesseh and Lin, 2016). As such, the co-benefits 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.[16]

Fig. 3-1 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.

[16] The Intergovernmental Panel on Climate Change (IPPC) defines co-benefits as 'are the positive benefits related to the reduction of greenhouse gases' and they include 'economic co-benefits' such as energy security, increased employment and technological innovation (IPCC, 2007).

Figure 3-1 Framework for exploratory research



3.2.2. 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 3-1.[17] We discuss these in turn.

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

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

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 3-1 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.

Table 3-1 Factors for exploratory research

Factor	Characteristics	Key references
Nature and flows of capital and technology	• Technologies and their components • Lead agents involved • The nature of finance	(Brautigam & Hwang, 2019; Kaplinsky & Morris, 2009; Lema et al., 2018)
Local institutional and economic conditions	• Host economy deployment model • Industrial policy-environment • Domestic supply base	(Baker & 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, Gregersen, Lema, Samoita, & Wandera, 2018)

Local institutional and economic conditions

Another important determinant is the local context of project execution in terms of endowments of human and organisational capabilities, as well as the institutional and political environment. Outcomes depend crucially on existing supply chains and the capabilities of both local firms and project owners (Lema, Iizuka, and Walz, 2015). A highly asymmetrical distribution of capabilities between local and foreign (here Chinese) actors may limit the scope of co-benefit creation, as well as vice versa. Local bargaining power may be limited, but deliberately devised policies and strategies may influence the opportunity to reap benefits through models of project organisation and execution which deliberately seek to enhance their creation (Baker and Sovacool, 2017; Power et al., 2016). Institutional conditions and regulatory frameworks can play a key role in mediating these conditions, for example, by stimulating local production through local content requirements, public procurement regulations and industrial policies (McCrudden, 2004; Lema et al., 2018). Specifically in the case of renewable-energy projects, a number of deployment models and related policies may be used to support their diffusion, ranging from market-based systems, such as auction schemes, to directly negotiated contracts on an individual basis, such as government-to-government agreements (Leigland and Eberhard, 2018; World Bank, 2016).

Generally, there is a move toward the use of competitive bidding systems world-wide 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.

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. 3-1.

3.2.3. ECONOMIC CO-BENEFITS

We examine three main types of co-benefit: employment, local content and technological learning Table 3-2.[18] Since the core of our empirical analysis is concerned with benefits, it is important to specify these further:

Job creation

Project investment may include various types of local jobs. Existing research has shown that the employment-creation potential and involvement of local labour differ with the type of renewable energy, the size of the project and the nature of the value chain (Hansen, Gregersen, Lema, Samoita, and Wandera, 2018). Local employment 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.

Local content

Foreign investment projects may be organised in very different ways depending on the type of technology involved, the availability of local supply chains for the creation of backward linkages, the investment strategy and the policies that regulate investments (Tsani, 2020; Wells and Hawkins, 2010). Local content refers to those services, materials and capital goods used to deliver the project that are local rather than imported, divided into direct content (in the project) and indirect content (in local supply chains).

Technological learning

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

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[18] 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.

out-side 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 3B which describes our composite indicators and helps to situate and interpret our findings.

Table 3-2 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, Pachauri, & Steinbacher, 2016; Suberu, Mustafa, Bashir, Muhamad, & Mokhtar, 2013)
Local content	• Involving of local firms and local supply chains • Involving local universities or knowledge institutions • Involving local communities • Access to infrastructure	(Hanlin & Hanlin, 2012; M. W. Hansen et al., 2016; U. E. Hansen, Nygaard, Morris, & Robbins, 2020; Wells & 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 & Mallett, 2013)

3.2.4. 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).[19] 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

[19] 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).

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 3.4 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 3B 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).

3.3. 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.

3.3.1. 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 3-3 Total installed capacity of hydro, wind & solar power in Africa

Technology	2009	2018	Countries with largest share of total capacity
Hydro power	26 GW	35 GW	Angola, Ethiopia, South Africa, Zambia
Wind power	739 MW	5.5 GW	Egypt, Ethiopia, Morocco, South Africa, Tunisia
Solar power	108 MW	6.1 GW	South Africa, Morocco, Egypt, Algeria, Kenya

Sources: IRENA (2013, 2019)

Table 3-3 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.

3.3.2. 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 3-4.

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 con-tent requirements' involving Chinese EPC and technology providers as a part of financing deals.

Table 3-4 Key Chinese EPC contractors and technology suppliers

<table>
<tr><th>Power</th><th>Finance</th><th>EPC Contractors</th><th>Technology Suppliers</th></tr>
<tr><td>Hydro</td><td rowspan="3">• China Export-Import Bank (China Exim Bank)
• Chinese Development Bank (CDB)
• Sinosure
• Industrial Commercial Bank of China (ICBC)
• Bank of China (BoC)</td><td>• Sino Hydro
• PowerChina Resources
• Three Gorges Corporation</td><td>• Dongfang Electric Corporation
• Harbin Electric Corporation
• Shanghai Electric Power</td></tr>
<tr><td>Wind</td><td>• CGC Overseas Construction Group
• Hydro China
• Longyuan Power Group</td><td>• Goldwind
• Sany
• Sinovel</td></tr>
<tr><td>Solar</td><td>• China Jiangxi Corporation
• Powerway
• Beijing Xiaocheng</td><td>• JinkoSolar
• Yingli
• JA Solar</td></tr>
</table>

Sources: (Chirambo, 2018, Shen and Power, 2016 & Tan-Mullins et al., 2017)

3.3.3. EPC CONTRACTORS

Table 3-4 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 civilengineering projects in the energy sector.[20]

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.

3.3.4. 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 3-4, have increasingly moved into sub-Saharan Africa (Shen, 2020). Table 3-5 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 massive 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.

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

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).

Table 3-5 Export of hydro, wind and solar equipment from China to Africa 2006-2016

	Export of equipment from China to Africa (in 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	46.16	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

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.

3.4. INSIGHTS FROM THE THREE PROJECTS

This section draws on primary data to examine the key factors and indicators developed for this analysis (in Section 3.2). Three sub-sections describe each of the case-study projects in turn. Table 3-6 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.

Table 3-6 Overview of the projects' actors and roles

		Garissa	**Adama**	**Bui**
Capacity and ownership	Energy source	Solar PV	Wind	Hydro
	Size	55 MW	204 MW	400 MW
	Owner/ sponsor	Kenya Rural Electrification Authority (KREA)	Ethiopian Electricity Power (EEP)	Bui Power Authority (BPA)
Service delivery	Electricity distribution	Kenya Power and Lighting Company (KPLC)	Ethiopian Electric Services (EES)	ECG/Gridco
	Plant operation	Kenya Electricity Generating Company (KECG) and CJCI	EEP	Sino Hydro
	Plant maintenance	KECG	EEP	Sino Hydro
Infrastructure delivery	Finance	Export-Import Bank of China (USD 140 Mio)	Export-Import Bank of China (85%) Government of Ethiopia (15 %)	Export-Import Bank of China (USD 500 mio.); Gov of Ghana (USD 60 Mio);
	EPC and project management	China Jiangxi Corporation for International Economic & Technical Cooperation (CJCI)	HydroChina & CGC Overseas Construction Group	Sino Hydro
	Front-end and detailed engineering	CJCI and Maknes Consulting	HydroChina & CGC Overseas Construction Group	Coyne et Bellier (France) and Sino Hydro
	Core technology supply	JinkoSolar (China)	Goldwind (China) & Sany (China)	Produced in China by Alstom (France)

3.4.1. 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.[21] 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.[22]

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 Hydro-China 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

[21] Primary data for the Adama case was gathered during November 2017 from 11 key informant interviews with key stakeholders. Fieldwork included a site visit and informants include project managers, engineers, consultants and policymakers. In addition to publicly available sources, recent studies by Chen (2016; 2018) with an analysis of technology transfer in both the Ashegoda and Adama wind power projects in Ethiopia provided further useful information, in particular on number of jobs created and information sessions for local communities.

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

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, 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.[23] 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

[23] 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.

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.

3.4.2. 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.[24] 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)[25] 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

[24] This case study is based on eighteen interviews undertaken with Chinese and Ghanaian informants over a six months period. Intreviews were semi-structured and conducted with relevant stakeholders from the public sector, the private sector as well as civil society. This data was complemented by a review of more than 100 newspaper articles about the Bui Dam (dating from 2001 – 2020). The research also benefitted from prior research on the case (Hensengerth, 2018; Kirchherr, Disselhoff, & Charles, 2016).

[25] 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).

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 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.

3.4.3. 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.[26] 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 sup-ply panels, and with Byd for inverters. CJIC also subcontracted two Chinese companies for project design and civil

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[26] Primary data for the Garissa case was gathered during October 2017 from nine key informant interviews and one focus group discussion with local stakeholders. Fieldwork included a two-day site visit and informants includes Chinese project managers, workers, and the project liaison officer in Garissa County. Additional interviews in Nairobi included staff at REA and EPRA. 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 entailed in the O&M phase.

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.[27] 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.[28]

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

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

[28] 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.

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.

3.5. 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 3.2, 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.

3.5.1. ECONOMIC CO-BENEFITS

Table 3-7 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 3B 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 3.2. 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.

Table 3-7 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 involved in operations and routine maintenance undertaken by BPA. Sino Hydro employed in new contract for additional repair construction.	During, the project employed 50-75 Chinese staff and nearly 350 local staff, a majority of whom were involved in low-skill activities. During operation stage, five Kenyan staff and four Chinese nationals are involved.
Local content	No local equipment or construction service inputs. Local involvement in the projects physical completion was confined to transportation services (on-land shipping of the turbines). Turbines and other critical equipment sourced from china. Important involvement of a local university 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% local content overall, however with critical equipment and components (e.g. turbines) provided from outside.	Local equipment inputs and construction services were limited to provision of auxiliary hardware (e.g. cables and wires). Important involvement of local engineering firms. In addition, functionally unrelated infrastructure was provided, including a school, which included local content
Local learning	Inbound flows of hardware from China along with end-to-end 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 operation and maintenance and associated certification. Training in China of personnel across state-owned electricity organisations,	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 the Sino-hydro. Deliberate training efforts confined to two-week bootcamps for labourers 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 3-8 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 localisation possibilities were limited to downstream activities, incl. peripheral procurement, installation services and O&M. EPC mandated to be Chinese in tied financing option, with no local co-financing option, limiting local content. CJIC favoured Chinese technology suppliers.
Local institutional and economic conditions	The institutional foundation was based on direct negotiations between project developers and EEP. The universities' strategic involvement 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-determied 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 based 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.

3.5.2. THE NATURE OF INBOUND FLOWS OF CAPITAL AND TECHNOLOGY FROM CHINA

As shown in Table 3-8, 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 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 Hydro-China/CGOCCC, as the EPC contractors negotiated the contract and all contingent decisions. In the Bui case, the Chinese technology suppliers and EPC contractors also followed the Chinese investors in a tied-finance agreement. It was a requirement that investors had to produce the equipment in China in order to be eligible for export support. A non-Chinese contractor (Alstom) also received economic benefits because the equipment used in the project had been produced in China. Moreover, the contractual arrangements for this project, using an EPC contract, could have been more advantageous to the Ghanaian stakeholders, with the MoE and

BPA likely to benefit much more from a build-operate-transfer (BOT) contract, which would have legally obliged Sinohydro to build the capacities needed for BPA to maintain the Bui Dam. On the other hand, an EPC contract was much more in the interests of Sinohydro, since it might have created additional contracts, for example, for project maintenance, once the first contract had been completed.

3.5.3. 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 circum-vented (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).[29]

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

[29] 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).

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.

3.5.4. 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.

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.

3.6. 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.

3.6.1. MAIN FINDINGS AND POLICY IMPLICATIONS

The project-level analysis described in Sections 3.4 and 3.5 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.

3.6.2. 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.

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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 3A: Explanatory variables

This appendix provides further information on the operationalisation of the key explanatory variables. Table 3A-1 shows our framework for data collection and analysis and is a complement to the information provided in Section 3.2.2.

Table 3A-1. 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

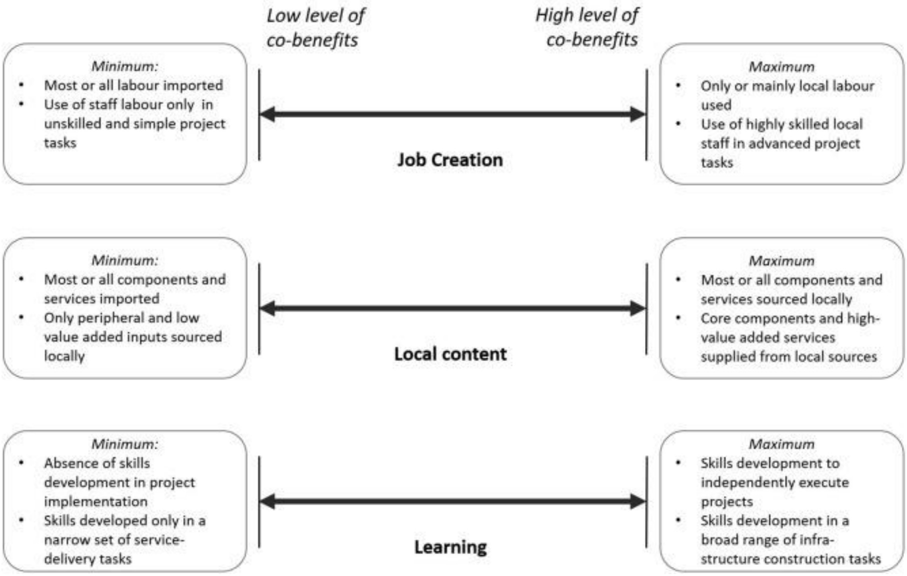
Appendix 3B: Economic co-benefits

This appendix provides additional information and discussion about the co-benefits and related indicators presented in Table 3-2 of Section 3.2.3 and serves as the basis for interpreting the empirical findings presented in Section 3.2.4. 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. 3B-1** 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 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. 3B-1, 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 et al., 2016, Suberu et al., 2013).

Figure 3B-1 Conceptualisation of minimum and maximum levels of co-benefits



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).

CHAPTER 4. LOCAL LEARNING AND CAPABILITY BUILDING THROUGH TECHNOLOGY TRANSFER: EXPERIENCES FROM THE LAKE TURKANA WIND POWER PROJECT IN KENYA

ABSTRACT

This paper contributes to the ongoing debate in innovation and development studies on renewable energy projects and their contributions to sustainable industrialisation through the accumulation of innovation capabilities. Based on a case study of a large wind power project in Kenya, this research explores technology transfer and interactive learning processes to accumulate local capabilities. The study emphasises the multiplicity of actors involved in complex infrastructure projects and explores the nature of their relationships and interactions through the research question: What are the opportunities and limitations for local learning and capability building through technology transfer in large renewable-energy infrastructure projects? Identifying interactions across multiple phases of the Lake Turkana Wind Power project, the results show that multiple loops of interactions foster better local-learning opportunities. Wider project learning and learning for sustainable industrialisation require deliberate investments to build collective capabilities.

Key words: Technology transfer, wind power, local learning, technological capabilities, Lake Turkana Wind Power project, Kenya

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CHAPTER 5. INTERACTIVE LEARNING SPACES: INSIGHTS FROM TWO WIND POWER MEGAPROJECTS

ABSTRACT

Kenya and Ethiopia are frontrunners in the region when it comes to adding wind power to their power generation capacity and there is high interest from project developers. The chapter uses the lens of 'interactive learning spaces' to understand how interactions between different stakeholders in a megaproject can lead to the accumulation of technological and managerial capabilities. The two projects offer interesting and different examples of the types of learning spaces in which the transfer of both formalised and tacit knowledge can occur. The chapter argues that it is important to understand and deliberately create and nurture such interactive learning spaces in order to spur and sustain local skills upgrading and capability-building in connection to large infrastructure projects based on imported key technologies.

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5.1. INTRODUCTION

The Lake Turkana Wind Power (LTWP) project in Kenya and Adama II in Ethiopia are two of Africa's largest wind power plants in terms of megawatt (MW) installed. When fully deployed and running, they will contribute substantially to secure better access to reliable energy to households and businesses in Kenya and Ethiopia using sustainable sources of energy such as wind. However, will the two turnkey projects based on imported key technologies also generate local skills upgrading and local capability-building? This question has its roots in a long tradition of technology transfer and development literature emphasising the potential of a variety of flows of knowledge and technologies following large turnkey projects (Bell 2007, 2012). Often such large infrastructure projects generate several local low-skilled jobs related to the construction phase but very few local high-skilled jobs. Management and engineering jobs are often supplied from abroad together with the key technologies. When a turnkey project is delivered and the foreign experts have left the country, the sustaining local capability-building is often very limited as Rennkamp and Boyd (2015) confirmed in their study of technology transfer in relation to wind and solar projects in South Africa. Nevertheless, in this chapter we show that a deliberate creation of interactive learning spaces can be one way to establish, maintain, and further develop local high-skilled jobs in relation to large turnkey infrastructure project even with key technologies imported.[30]

In short, 'interactive learning spaces' are defined as 'situations in which different actors are able to strengthen their capacities to learn while interacting in the search for the solution to a given problem' (Arocena and Sutz, 2000, p. 1). Interactive learning spaces integrate the coexistence of learning capabilities and learning opportunities in a specific context. An interactive learning space is therefore a social space created as an opportunity for knowledge producers and users to build innovation capacity, and to devise solutions to specific social and economic problems through interaction.

Relevant learning processes related with problem solving include the capacity to recognise the useful existing knowledge, to detect the missing knowledge needed, to organise the search process to acquire it, to inte-grate new knowledge into the previous base and the whole into current practices. (Arocena & Sutz, 2000, p. 7)

There are clear overlaps to Cohen and Levinthal's absorptive capacity concept defined as 'the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends' (Cohen and Levinthal, 1990, p. 128). Learning is cumulative and path-dependent or in other words, absorptive capacity depends on the level of prior related knowledge. Introducing the interactive learning space concept in

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[30] See Andersen and Lema (2022) for a broader discussion of three key elements in the renewable electrification process: learning, development of capabilities and the resulting outcomes.

the current chapter underlines the focus on when and under what institutional settings absorptive capacity may develop and how it can be supported by a deliberate process. The institutional settings within and around the projects, and the ability to shape these to foster capability accumulation, are key in shaping the path from technology adoption to learning and innovation (Lema, Iizuka, and Walz, 2015). Furthermore, the idea of creating deliberate learning spaces within projects relates to the literature which looks at the criticality of inter-project learning and cross-project learning (Davies and Hobday, 2005) and how projects may stimulate learning and function as arenas for learning (Lundin and Midler, 2012).

Creation of interactive learning spaces can emerge and develop as a process where actors identify and solve relevant problems - as a reactive process. Interactive learning spaces can also be created as a deliberate and proactive strategy to build capacities and create learning opportunities (Johnson and Lundvall, 1994; Johnson and Andersen, 2012; Petersen et al., 2018). In practice, the two forms can interact and mutate into new mixed forms, for instance if a concrete university-industry collaboration project involving a couple of staff develops into a broader collaboration framework between the university and the external partner for starting more student projects and scholar engagement in the future. In both the LTWP and the Adama II case, we focus on two examples of interactive learning spaces that fall into the category of being created as a proactive strategy to capability-building.

Assuming that learning spaces are embryonic points in the development of innovation systems (Arocena and Sutz, 2000), it is relevant to identify and study them empirically - how they emerge, grow, and disappear. In situations where technologies are imported as turnkey projects including agreements on operation and maintenance, the learning opportunities and capability-building for local companies and organisations may be very limited, if a proactive approach to creating learning opportunities is not applied. Even when a proactive approach is in play it still takes continuous investments in learning and capability-building to maintain and accumulate new knowledge.

Deployment of large wind parks is a complex process involving a very broad range of skills and knowledge types, technologies, people, procedures, and organisational arrangements within the different phases from the planning and project development phase to the production and construction phase, to the final electricity production and maintenance phase. The two wind power projects (LTWP and Adama II) show variations in their set-up, the partners engaged, and the energy systems in which they are embedded, but using the lens of interactive learning spaces on the two case study projects helps us understand how interactions between different stakeholders can lead to accumulation of technological and managerial capabilities. The distinction between multiple learning spaces in these projects bears a resemblance to the ideas of Davies and Brady (2000) that an organisational learning cycle must be put in place to learn from the multiple sets of capabilities required in complex projects.

The analysis of the two wind power projects draws on data collected during site visits to the Adama II project in November 2017 and the LTWP project in December 2017.[31] In addition, secondary data such as policy documents, press releases, journal papers, and project webpages support the analysis.[32]

The analysis is structured according to two types of interactive learning spaces. One is a project management interactive learning space related to the project development and construction stages of the wind parks. The other is an interactive learning space related to the operations and maintenance phases of the projects. In each case we:

1. Introduce the specific context and institutional settings of the megaprojects, including identifying the key actors - who is interacting with whom.
2. Analyse how a proactive strategy of creating an interactive learning space can spur capability-building in project management as an example of local high-skilled capability-building.
3. Analyse how a proactive strategy of creating an interactive learning space can spur capability-building within operating and maintenance of the wind turbines as an example of local medium to high-skilled capability-building.

In the following, first the Adama case and then the Lake Turkana Wind Power case is presented. The main learning from the two cases is discussed followed by a conclusion.

5.2. THE ADAMA II WIND POWER CASE

5.2.1. KEY ACTORS IN THE ADAMA WIND POWER PROJECT

The Adama wind power project, Adama I and II, in Ethiopia is owned by the state-owned electricity producer Ethiopian Electric Power (EEP). It is a joint venture between the Chinese turnkey contractor HydroChina and the CGCOC group, a Chinese construction company. Phase I was finalised in 2012 and added 51 MW to the electricity grid. Phase II was commissioned in 2015 adding an additional 153 MW to the grid.

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[31] A total of 37 semi-structured interviews with key actors were conducted between February 2017 and February 2019 focusing on the employees' roles, relationships with project members and practices of collaboration, coordination and interaction.

[32] A more detailed analysis of the relations and interactions of the LTWP case study can be found in Gregersen (2020), while the Adama case study is also featured in Lema et al (2020). The findings presented in this chapter draw upon the analysis of these studies but views and discusses them through the lens of interactive learning spaces.

The total investments of US$ 462 million (US$ 117 million in phase I and US$ 345 million in phase II) of the projects were financed by preferential export buyer's credit from the China Exim bank (85%)[33] and own capital of EEP and the Government of Ethiopia (15%).[34] The financing agreements specified that Chinese wind turbine generator (WTG) technology was to be used. For Adama I, a Goldwind direct drive model (GW77 /1500) was used while Adama II was completed with a gear box model from Sany (model SE7715). The following presentation of findings will focus specifically on interactive learning spaces occurring in Adama II's overall management of the construction phase and the succeeding maintenance phase.

As a turnkey contractor, HydroChina was responsible for the entire industry chain, from design and financing right through to engineering construction, equipment, and project contracting. They have multiple design and construction teams in China, and HydroChina's project manager for Adama II explained how they were able to work with the teams with the most experience required for this type of project (e.g., turbine model and construction requirements). The investment model, design, and blueprints from the project were proposed by HydroChina and CGCOC and negotiated with EEP. The final Engineering, Procurement, and Construction (EPC) contract included the design, manufacturing, supply, installation, testing, and commissioning of the project, including all ancillary works and civil works.

Following on the practice of the Ashegoda wind power project and Adama phase I, the Government of Ethiopia requested that Ethiopian universities submit proposals to act as owners' consultants on the project. For phase II, EEP hired a team of consultants from two Ethiopian universities (from Adama Science and Technology University (ASTU) and Mekelle University (MU)) as construction supervisors and contract administrators. According to the terms of reference, the aim of bringing in the university consultants was to:

- Build the capacity to implement construction contracts based on foreign technologies and suppliers,
- Build the capacity to manufacture main components such as towers and blades, and
- Eventually to build the capacity to manufacture and develop own technology.

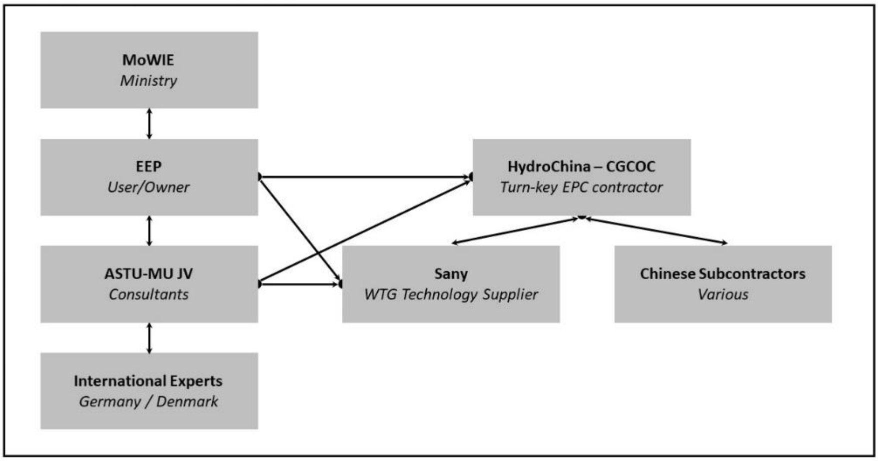
At the peak construction period, HydroChina is estimated to have had over 200 employees working on site. The managing team was around 20-30 employees from HydroChina's head office, including subsidiaries. The construction teams were specialised in for example transmission lines, sub-stations, and turbine erection. Sub-

[33] At an interest rate of 2%.

[34] The investment estimation did not include permanent and temporary land compensation expenses.

contractors included Beijing Engineering Corporation Limited, 'Bureau no. 5', and SinoHydro - all under the HydroChina mother company. While all sub-contractors were Chinese, a large number of Ethiopians were employed during the project construction. The large number of Chinese employees during this phase reflects that the job types varied and that the project management (also based on the CVs of HydroChina's key personnel) was mainly carried out by Chinese employees. The key project management personnel counted approx. 13 Chinese staff for phase Il, ten of which had already worked on phase I. Figure 5-1 illustrates the key actors involved in the Adama II project.

Figure 5-1 Key actors involved in Adama II project



Source: authors

5.2.2. INTERACTIVE LEARNING SPACES AND CAPABILITY-BUILDING IN PROJECT MANAGEMENT

In Adama II the team of consultants from Adama Science and Technology University (ASTU) and Mekelle University (MU) signed a joint venture to engage in the consultancy contract. The consulting team was made up of 17 academics from the two universities, working as project managers, a resident engineer, and three teams of engineers: civil engineers (structural, geotechnics, and a surveyor); power/electrical engineers (SCADA, communication, control, machine); mechanical engineers (structure and aerodynamics); and one environmental expert. These three teams mirrored the set up on EEP's team, while HydroChina's teams included the design team, construction team, and the managing team.

The Chinese teams were brought in to complete their respective tasks during implementation for short periods of time, to save time. For some civil works, for example ditch construction, only a Chinese foreman was involved to instruct workers based on the overall planning and design. In terms of choice of employees, locals who were affected by the land use were offered employment first, e.g., in civil works or as guards. According to a project manager, HydroChina's salary was two to three times higher than an average salary would have been for these workers. The university consultancy team's main tasks were to manage the overall supervision of the implementation of the project in contract administration and design verification, including:

- Optimised energy prognosis
- Approval of WTG selection
- Substantiation of micro-siting for turbine layouts
- Construction and erection supervision
- Acceptance testing start up, commissioning, and initial operation of the plant
- Handover of the project and preparation of project manuals, reports, etc.

As specified in the contract, the university consultants hired international experts, from companies such as the Danish wind turbine technology company, Norwin, and German rotor blade specialists, CP Maxx, who possessed the required knowledge in wind energy and wind turbine technologies. These international experts conducted training sessions with the university consultant team in their areas of expertise, including on issues regarding international standards, quality control, and inspection and reported on issues such as control of blades after transportation.

There were weekly meetings between the EEP manager, the consultants, and various teams from HydroChina. They would discuss progress made and plans for the following week. Sometimes deadlines were given for evaluations, negotiations about extensions on certain parts of the work, as well as negotiations about technical issues. There was a reporting mechanism to the Ministry of Water, Irrigation, and Electricity (MoWIE) and meetings with government officials, where every team head had to report their experiences. “It’s a kind of not only consulting, it was also an experience sharing, searching for us. Because it is a new project and the government is planning to expand it. So, a pool of experts was needed” (interview with university consultant, 11 November 2017).

The majority of university consultants came from technical backgrounds in thermal, industrial, and mechanical engineering, but they had not worked on wind energy projects before. The university consultants as well as EEP staff on the projects had received a number of training courses, including at the manufacturers' location in China, as well as on site. The desired skills transfer to the university consultants was specified as consultancy and project management skills. For EEP, the major skill to learn was how to control the contractor, e.g., what kind of reporting is most important, and what clauses should be included in the contracts in the future.

Bringing in university researchers as part of the knowledge transfer is specific for wind energy projects in Ethiopia and has not been done for example in the big hydro power projects. As mentioned, EEP has a duty to report to the Ministry (MoWIE) on the progress of the project and they pay particular attention to the issue of knowledge transfer:

> We will focus on knowledge transfer and how that is happening. And we will ask the employees there, EEP employee, whether they acquired desired knowledge or not. In that case there was for example documentation issues. The documentation issue and I think they say they don't reveal some design document or something like that. So, we try to solve that kind of problem and also, we will see also with their quality of material is up to the standard or not. We will ask our EEP partners about the quality of their Chinese work. (Interview with a ministry official, 13 November 2017)

However, challenges were outlined in the institutionalisation of such knowledge transfer, due to employee turnover from project to project: “I think the problem with knowledge transfer is that there is turnover of employee, that is the main problem. Like after they acquired some basic knowledge, there is a turnover of employees” (Interview with a ministry official, 13 November 2017).

5.2.3. INTERACTIVE LEARNING SPACES AND CAPABILITY-BUILDING RELATED TO MAINTENANCE

Part of the Engineering, Procurement, and Construction (EPC) contract specified that EEP staff were to receive training from HydroChina and Sany in order to hand over the maintenance and plant management tasks swiftly once operations started. There was a relatively short handover period from Sany (as technology suppliers in phase II) and HydroChina with only an Operation and Management (O&M) support agreement rather than the standard practice in the industry with a service agreement of five years or more. The required training in operations and maintenance will however have increased the skills transfer.

HydroChina had a team on site for three years for training purposes, particularly for EEP's engineers to train them on sub-station management, for example adjustment of power. Furthermore, a team from Sany was on site during the warranty period of the nacelles and to hand over and conduct continuous training in maintenance.

The training began already in the construction phase where EEP engineers and university consultants were invited to China for one month of training. According to interviewees, between 20-30 persons (engineers and supervisors) attended this training. The planned activities included factory visits, power plant visits, and classroom teaching. Once operations began there was a four-month training on site at Adama II. Two dedicated trainers from HydroChina remained on site after installation to conduct these trainings, one focused on WTG training and one focused on sub-station management. This training included classroom teaching as well as on-the-job training. The overall handover from HydroChina to EEP staff entailed the sharing of manuals and technical drawings of the WTGs and sub-station design, basic knowledge of how to run the WTG and the plant, standard processes for troubleshooting and reparations, as well as how to manage a maintenance team. As an interviewee recounted, the troubleshooting process aims to tell engineers to “follow this ticket” next time so the engineers have “no need to think by themselves” (Interview with a project manager, 9 November 2017). A challenge highlighted by HydroChina was how to create training programmes when levels of education varied to a much greater extent than expected or when it was unclear whether the counterparts were certified engineers or interns not yet finished with their education. In fact, HydroChina's project manager recounted how company training in HydroChina China is a long-term and continuous process including job rotation schemes, monthly examinations, and mandatory courses before promotions and operation codes exist for every employee on a power plant. Transferring such a plant management scheme from one organisation to another may be very challenging and the interviewees raised some challenges in the transfer of skills listing, e.g., differences in work culture between Chinese and Ethiopian engineers as a major hurdle, the level of acceptance of the Chinese '24/7' work culture, as well as inevitable lost in translation issues (interview with a project manager, 9 November 2017). It was reported, however, that one of HydroChina's long-term plans is to open a training centre in Addis Ababa.

5.2.4. SUMMARY

Overall, the case of Adama II illustrates how the Government of Ethiopia specifically created and institutionalised an interactive learning space by bringing in the university consultants. The aims of technology transfer were clearly outlined, and distinctive types of interaction arose between multiple actors in the project management of construction. As indicated in Figure 8.1, interactions were manifold between all key actors. During the operations and maintenance phase, a different type of interactive learning space occurred as defined by the support agreement between HydroChina, Sany, and EEP. This learning space was defined by standardised learning opportunities related to handover of WTG operations and sub-station management including classroom teaching and on-the-job training for EEP engineers.

Despite the efforts to be proactive and design these interactive learning spaces, several challenges arose in the interactions and the subsequent transfer and use of the knowledge generated by the consultants involved in the projects. New teams were formed for each wind project without handover from the previous project other than EEP's own project reports. In addition, HydroChina and Sany, the project developers, were responsible for the design, installation, and construction from beginning to end, with different units from headquarters fulfilling each task. Local staff was hired for some construction jobs but otherwise the staff was largely Chinese. Some of the challenges mentioned for the actual knowledge transfer include:

- Communication difficulties, including the use of translation during the training courses.
- Problems in relation to sharing documentation from the manufacturer and labelling in Chinese rather than English.
- High turnover of EEP staff - one of the reasons for continued training courses for new employees.

Further, a number of sources of conflict strained the relations between suppliers and users and the consultants as intermediaries, including disputes over the verification of parts of turbines delivered being new or used, e.g., the installation of old generators on the project painted to look new, and general suspicion of the quality of Chinese products and unplanned changes for cost reduction. The university consultants recounted that while Chinese project managers maintained that things were done to plan, local staff shared different information regarding how the project was progressing. Similar challenges occurred when discussing whether manufactured goods and design of the sub-station followed international or Chinese standards; Sany's production in China follows the Chinese national standards for the industry which was according to the equipment contract.

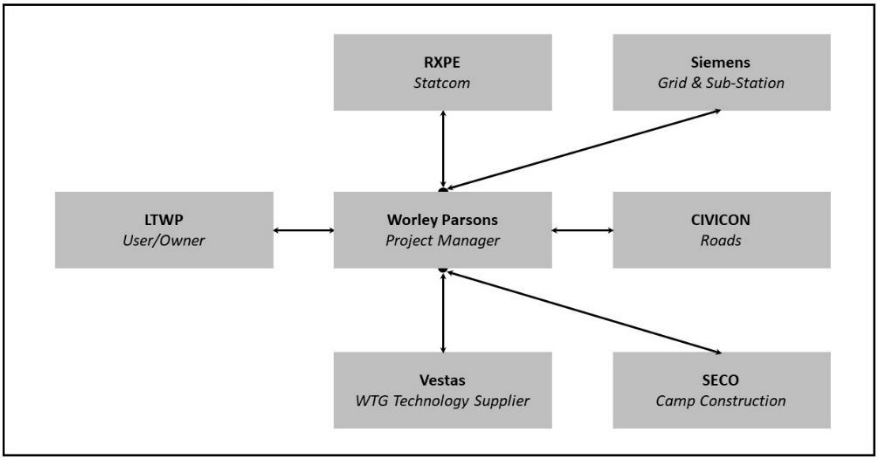
5.3. THE LAKE TURKANA WIND POWER CASE

5.3.1. KEY ACTORS IN THE LTWP WIND POWER PROJECT

The LTWP project in Kenya was the largest wind power project in Africa with its 310-MW installed capacity upon commissioning in 2019. The total costs of the project reached EUR 678 million and covered the installation of 365 wind turbines in a remote area in the Marsabit region in Northern Kenya. The project furthermore entailed the construction of more than 428 km new transmission line as well as the upgrading of over 200 km of roads and various bridges. The project is operated as an independent power producer (IPP) owned by the LTWP consortium.

The project owners hired an international engineering consulting company, Worley Parsons, for the engineering, design, and construction management (EPCM) contract. In essence, this contract was an overall project management contract to ensure 'interfacing', i.e., managing budgets and avoiding delays between work sub-contracted out to different suppliers. This is a typical kind of organisational arrangement in megaprojects where turnkey contractors are difficult to find (Steen, Ford, and Verreyne, 2017). As indicated in Figure 5-2, in the LTWP case, the project was divided into five main contractors: Vestas (wind turbine generators), Siemens (grid and sub-station), RXPE (Statcom - Static synchronous compensator), SECO (camp construction), and CIVICON (road construction). Worley Parsons acted as LTWP's 'eyes and ears' on site, ensuring the smooth collaboration between the five major contractors engaged for the construction phase. Each contractor hired sub-contractors to complete parts of their work, and local Kenyan firms were engaged by e.g., Siemens for part of the electrical cabling works. Other sub-contractors for e.g., Vestas included regional firm EGMF for work on the foundations and Bollore Logistics for the specialized transportation from Mombasa Port to the site. However, while Worley Parsons acted as project managers during the construction phase, in the many years leading up to the financial close of the project, the LTWP consortium and 'founding fathers'[35] of the project planned and designed the project in great detail. Thus, the choice of technology supplier, simulations of grid stability for a 310-MW wind power plant as well as road construction dilemmas and a number of other problem-solving activities were carried out by the owners.

Figure 5-2 Key actors involved in the LTWP project



Source: authors

5.3.2. INTERACTIVE LEARNING SPACES AND CAPABILITY-BUILDING IN PROJECT MANAGEMENT

Speaking to the project managers of the LTWP the project appears as very mission driven; they strived to complete an unparalleled project in a very challenging geographical location in order to prove to the world that such a project is possible. The project was developed as an Independent Power Project (IPP), and as the first major wind power project in Kenya it required new knowledge and skills for both project developers and regulators. The project developers faced and overcame a range

[35] The project was developed by a group of Dutch, Kenyan and Norwegian entrepreneurs who have been labelled as the 'founding fathers' of the project. They worked together with Dutch-registered KP&P, a company with history of developing and operating wind power projects.

of challenges from working with local communities (obtaining and maintaining their social licence to operate), negotiating the first Power Purchase Agreement (PPA) for wind in Kenya, to facing delays in externally managed critical parts for project commissioning (the transmission line) and subsequent critiques. The LTWP special purpose vehicle was established in 2006 to develop the feasibility studies, planning, and negotiations for the project which ran until financial agreement was reached in 2014, a period of eight years. Over this time and in response to multiple critiques the project was designed to specifically reflect commitment to involving the local communities both through employment plans and corporate social responsibility (CSR) activities. For example, contractors, such as Vestas with a long-term involvement, were asked to include training programmes.

> It was a requirement of LTWP to have some form of training, we couldn't tell them what to train them in, but had to say, you are here for 15 years doing O&M, so you are one of the companies that is here long term, we need to see you do some training, so they selected what they wanted. We didn't say you will do it on turbine maintenance but it's the obvious. (Interview with LTWP manager, 5 December 2017)

Despite the focus on CSR and community engagement, the project management approach described by interviewees was focused on interface management: identifying the critical paths of all the contracts, how they interlink and where risk of delays would be critical for the completion of the project. As indicated in Figure 5-2, this created a hierarchical design of interactions. However, within this structure here was a focus on intra-organisational learning through community recruitment. Sub-contractors were mandated to follow LTWP's aims of engaging local communities and prioritising job opportunities for the communities in the concession area before engaging Kenyan nationals from other regions of the country. While this was not guided by governmental requirements on for example local content, it was an approach that was constructed by LTWP in collaboration with key local actors as a strategy for 'earning and retaining' a social licence to operate. At peak construction, approximately 1,700 people were employed, the majority of whom were local (LTWP, 2017). Beyond the construction project management by Worley Parsons, LTWP can be identified as the key actor and repository of knowledge for capabilities on wind power project management. The 'founding fathers' accumulated the necessary knowledge through different activities of problem solving and searching as a result of their interaction with many different actors in the value chain of the project. According to one of the LTWP managers, none of the original team had previous experience in the wind industry. They simply had to learn on the job and bring in expertise:

> We just hit the ground running and said that this is what we are going to do and who can do what. We all decided and then we all went off and did our own bits and then we met once a month. We'd come back here from the field, sit, talk, this is what we have got to do and then we disappear again and come back

> again and meet the next month and just that's how we just got the ball running to start with. (Interview with LTWP manager, 5 December 2017).

LTWP's interactions with upstream and downstream actors proved an excellent channel for interactive learning for LTWP as an organisation. LTWP could be seen as an intermediator attaining the ability to translate codified analytical and engineering knowledge of suppliers in the wind industry to their down-stream partners (Kenya Power and Lighting Company, the Ministry of Energy and Petroleum, the Energy Regulatory Commission, the Kenya Transmission Company).

> Everybody involved had a huge learning curve because we employed or hired the cream of the crop across the globe on grid stability. KEMA for example, which is a Dutch company - we actually got them to do a study on the national grid system to see if it could cope with the power and they gave that report to the government, so they had to base plate to grow on and work on. And now KEMA is actually continuing to consult for them to make sure the grid works for all the other projects that are coming online. lt's been great for Kenya. lt's a fantastic project and so many people have learned so much. (Interview with LTWP manager, 5 December 2017).

During the planning and development phase (2006-2014), LTWP as an organisation accumulated experience by interacting with a very heterogeneous group of stakeholders, from the local authorities who had little experience in the type of negotiations for such a large-scale wind energy project, to contacting suppliers upstream in the value chain and convincing them of the business case. Furthermore, LTWP hired a large number of local unskilled labourers around the site for manual labour and site preparations. International expertise was brought in by hiring consultants and specialists to advise on the planning of the project, e.g., the experts from KEMA who made simulations of the grid integra-tion. Both LTWP as well as local authorities were able to use this as a learning experience and implemented their experiences when bringing the project for-ward (Gregersen, 2020).

5.3.3. INTERACTIVE LEARNING SPACES AND CAPABILITY-BUILDING RELATED TO MAINTENANCE

As mentioned above, the Danish wind turbine producer Vestas was contracted to supply and install 365 WTGs during the construction phase as well as to manage the operations and service of the WTG for a 15-year period once the project was commissioned. As an industry leader, the knowledge required to perform these tasks already exists within the organisation. However, formation of an interactive learning space can be identified in the process of recruiting and training a team of engineers that will work on the service contract for the first 15 years of this.

Vestas' philosophy is to have an interim phase between installation and operations, with an overlap between the two teams taking care of each of these phases. Part of the service team was therefore recruited before the full operations started, in order to ensure association with the construction and to assist during the con-struction. This strategy aims to ensure a smooth transition from the construction to the operations phase.

LTWP followed a recruitment policy that favoured the recruitment of as many workers as possible from the communities in the immediate geographical constituency of the project. This was translated into contractual agreements for all contractors and sub-contractors including a target of 20% of the total employment being from the communities in the region. Vestas set additional targets, to recruit up to 95% of their employees from the Northern Kenyan region (Interview, 4 February 2019).

The service team was recruited in teams of six. The first two teams recruited Kenyan technicians and diploma engineers with backgrounds in mechanical engineering, electronic communication skills, and higher level of experience (eight to ten years) within heavy engineering industries (e.g., with generators or in oil fields) (interview with service team manager, 4 February 2019). For the third and fourth teams there was a focus on hiring as many new university graduates from the immediate region as possible. In both teams, four or five of the selected technicians were from the communities living within and surrounding the project concession while the final recruitments for each team were made at the national level.

> So, these are the guys right now, the guys that you see walking around here in blue and black with Vestas on their back. They are all local, be it local local or from up country, who are currently maintaining the turbines so they have all had training already. [...] they were taken off to Denmark and [received] training on how to maintain this specific type of turbine. So, it is basically gearbox maintenance, checking oil, dust leaks, oil leaks, bearings of the nose cone of the turbines, the electrical to a degree. (Interview with LTWP manager, 5 December 2017).

Vestas technicians worldwide are required to undergo a standard global wind (GW) organisation training. Furthermore, Vestas has developed programmes for vocational and theoretical coaching and has a simulator on site at LTWP to train the service team in troubleshooting and maintenance of the turbines. Thereafter, ex-post training takes place on the job, both through a buddy programme pairing junior technicians with senior colleagues and by bringing in experienced service technicians from other Vestas departments. In the case of LTWP, technicians from Greece and South Africa were brought in to support the service team at the upstart of operations.

An on-site GW training kit on safety practices and 'train the trainer' programmes enable service team supervisors to undertake training for new recruits. Additional training needs based on skills and certification levels are available at Vestas' global training facilities. The key actors in the learning space that was created to train the Vestas service team are thus all within the global organisation Vestas, including the service team itself, the training facilities in Germany and Denmark, as well as the experienced service technicians who were brought in from other departments.

5.3.4. SUMMARY

The project management interactive learning space in the LTWP project is characterised by its mission driven and problem-solving approach. While Figure 5-2 illustrates a more hierarchical type of interaction this is limited to the construction management phase of the project. In fact, the interactive learning space for project management originated with the 'founding fathers' of the project who took on the role as the key actor and repository of knowledge. For construction management, project management was then outsourced to Worley Parsons and interactions among sub-contractors was limited to issues of interfacing and time management. The project management interactive learning space is therefore more broadly viewed as spanning from the project's conception and managing its development on a more holistic level, while project management of the construction period in itself was a different space where more limited learning may have been shared between actors. The LTWP interactive learning space on project management is not characterised by a proactive strategy on behalf of the government of Kenya.[36] Rather it is embedded in the existing energy system where IPPs are encouraged and therefore LTWP themselves had to create a space in which they could learn how to manage an IPP. Within this space they acquired the necessary knowledge about issues ranging from conducting feasibility studies for the site, road surveys, and grid simulations to what clauses to include in a power purchase agreement for wind power plants.

The maintenance learning space in the LTWP project is bounded by the organisational borders of Vestas (Gregersen, 2020). Because of the 15-year service contract the learning space is highly intra-organisational as Vestas needs to recruit and train a team of engineers to fulfil this contractual task. Although the team is project based, it is a long-term investment to train the employees which is backed up by the highly standardised educational programmes of the company, including the GW trainings, simulations, and on-the-job training.

Interesting questions arise as to whether the experience-based learning in the LTWP case results in 'local' knowledge, especially as the learning space in the maintenance

[36] At the time of LTWP's development there were no local content regulations beyond the oil and gas sector in Kenya, however, the 2019 Energy Act has emphasised the need to develop local capabilities to manufacture, install and maintain renewable energy and stipulates that firms are expected to submit local content plans, including the use of Kenyan contractors and staff were qualified and available (Hanlin, Okemwa and Gregersen, 2019).

phase is defined as exclusive to Vestas employees. Furthermore, the learnings accumulated by the LTWP developers is bounded by the project-based nature of the power plant and the uniqueness of the project. The prospective wind power plans in Kenya have been limited to projects that are much smaller in size and there are no concrete plans for LTWP to develop and own more wind projects at the time of writing.

5.4. LEARNING FROM THE TWO CASES

Looking across the two cases there are interesting similarities and differences concerning where and under what institutional setting the two large wind power projects have created local interactive learning spaces with opportunities for skills upgrading and local capability-building. In large complex infrastructure projects like Adama II and LTWP, multiple organisations and complex interactions are involved, and in principle all actors may gain experience and obtain new or adjusted knowledge that may be accumulated and used within the project as it develops and/or is transferred to another context. While such learning by doing, using, and interacting is key as it emerges and takes place everywhere all the time during a concrete project, it also raises an important question, as to whether learning spaces can be deliberately designed to support skills upgrading and local capability-building in the long run. Based on the analysis earlier in this chapter, two parallel examples in each of the two wind farm projects were selected to serve as illustrations of such deliberately designed learning spaces. One learning space is connected to managing the process and the other to maintenance. The different phases have different involvement of actors, activities, key technologies, and requirements of knowledge domains. While other studies have introduced the concept of project capabilities, referring to important activities of bid preparation and project execution (Davies and Brady, 2000), this chapter shows that it is useful to make even further distinctions in the organisational learning cycle of wind power projects.

The Adama II and LTWP cases have raised interesting questions regarding the promotion of learning within and across organisations. Jensen et al. (2007) argue that firms can promote the doing, using, and interacting mode of learning by building structures and relationships which enhance and utilise learning by doing, using, and interacting (e.g., project teams, problem-solving groups, and job and task rotation, all of which promote learning and knowledge exchange). Project-based construction is thus necessarily interactive and problem solving. However, the two wind power project cases show important differences in the way interactive learning spaces can be designed and shaped to proactively contribute to a desired future. The case of Adama II has an interesting institutional setting supporting high skilled knowledge transfer. From the very beginning, Ethiopian universities became involved on a contractual basis with the explicit aims to secure knowledge transfer and local capability-building on wind technologies. The LTWP project did not have a similar involvement of universities or other national public knowledge institutions. Instead, skills upgrading and capability-building were regulated by contractual agreements between LTWP and a number of different sub-contractors. To secure that knowledge transfer and experience-based learning become locally rooted may be more difficult under this institutional construction. Table 5-1 summarises the main characteristics of the four selected interactive learning spaces.

Table 5-1 Main characteristics of selected learning spaces

Management learning space	**Adama**	**LTWP**
Context and institutional setting	• EEP-owned power project designed, constructed and handed over by Hydro-China-CGCOC	• Independent power project developed, designed and operated by LTWP
Key actors	• EEP • HydroChina-CGCOC • ASTU and MU	• LTWP • Kenyan authorities
Capabilities in focus (direct/indirect skills)	• To manage and implement construction contracts	• To manage and implement construction contracts
Reactive or proactive by design	• Designed by GoE to involve universities in the contract management and supervision	• Emerging with elements designed by financial stakeholders to involve training of local workforce
Inclusive or exclusive	• Inclusive	• Inclusive
Maintenance learning space	**Adama**	**LTWP**
Context and institutional setting	• Short term handover contract	• 15-year service contract
Key actors	• Sany • EEP	• Vestas
Capabilities in focus (direct/indirect skills)	• Operations and maintenance of the WTG and plant management	• Operations and maintenance of the WTG
Reactive or proactive by design	• Designed by HydroChina/Sany	• Designed by Vestas
Inclusive or exclusive	• Exclusive	• Exclusive

Source: Authors' own elaboration

In both the Adama II and LTWP cases the learning spaces for maintenance are characterised by efforts to codify knowledge through manuals and tailored training programmes. However, the need for other modes of learning is shown in the complementarity of on-the-job training programmes and 'buddy' systems, that foster informal communication and sharing. This mobilises the tacit knowledge of senior technicians as well. Empirical work has shown that both tacit and codified modes of learning and innovation play a role and in fact the combination may promote more innovation than either or (Jensen et al., 2007).

Johnson and Andersen (2012) point to the importance of inclusivity of learning. On a general level, inclusion refers to broad and active participation in a process of change. The project management learning spaces may possibly be viewed as more open and diverse in terms of the actors involved. Other empirical studies have proposed that the type of relational activities of project management include capability-building exercises, as the process itself becomes a learning experience as the team gradually develops its resource base (Soderlund, Vaagaasar, and Andersen, 2008; Hanlin and Okemwa, 2022). The case of Adama was explicitly designed to include universities (staff and students) while LTWP engaged many different stakeholders in a problem-solving process driven by the developer's interest. The maintenance learning spaces were more exclusively operated between trainers and engineers with a hierarchical structure. In the case of Adama this involved an inter-organisational transfer of knowledge while in LTWP this consisted of the accumulation of capabilities by a team within the organisation. The cases of learning spaces in maintenance highlight that despite their exclusivity, they are in fact spaces in which experience and knowledge can be applied in a formalised and tested learning culture.

Inclusion of universities as a proactive strategy is a way to ensure that knowledge and experience is shared in a key renewable electrification effort. However, while the inclusion was formalised in terms of a contract and specific tasks being outlined, it is also important to pay attention to the quality of the interactions and linkages. Particularly, problems of trust between actors can arise when the vision or mission has not been created together. For example, the university consultants in Adama expressed feelings of not being able to change anything that was already agreed or designed between HydroChina and EEP. Their mandate limited their role beyond objecting and waiting for rectifications during the construction phase. Johnson and Andersen (2012) do note that interactive learning spaces give rise to learning linkages mostly within the boundaries of the interactive space itself. As a consequence, reflections about inclusivity/exclusivity are important through all phases of such projects. Circling back to the mission setting of an interactive learning space one could question what opportunities exist for learning in exclusive learning spaces to be used beyond the learning spaces boundaries. For example, what opportunities do the service engineers of Vestas have to use their new knowledge beyond maintenance of the WTGs in Lake Turkana? Does any discussion of their experience feedback to Vestas' headquarters and training facilities? What opportunities do the university consultants have to use their acquired skills in project and contract management? How realistic are the efforts taken to ensure technology transfer for the longer term aims of component manufacturing in Ethiopia? Should one learning space be followed by another once it has been 'shut' (for example after the end of the contractual obligations binding HydroChina, EEP, and the university consult-ants' interactions)? These questions relate to discussion on the importance of avoiding 'de-learning', i.e., when interactive learning spaces are shut down or disappear (Arocena and Sutz, 2000).

5.5. CONCLUSION

In this chapter we showed that by a deliberate creation of interactive learning spaces it is possible to establish and further develop local high-skilled jobs in relation to large turnkey infrastructure projects when key technologies are imported.

The two large wind power projects (Adama II and LTWP) formed the point of departure to examine and engage with the concept of interactive learning spaces in global collaborative efforts towards renewable electrification. Interactive learning spaces have provided a way to understand micro-level interactions between different group of actors in specific contexts. In particular, the way in which future infrastructure projects are conceived in policy, as well as designed, developed, and implemented in practice. Issues of directionality, distribution, and diversity of learning spaces need to be raised and considered - is a learning space designed to be inclusive or exclusive? What efforts can be made to identify, foster, and protect interactive learning spaces? The ways to do this are manifold, depending on the problems and the actors around which the learning places are constituted within renewable electrification efforts at large. In particular, thinking of such wind power projects as opportunities to search for and apply knowledge is part of creating systemic learning from project to project. This has implications for policy making for a learning-based industrialisation, where focus is rather on collective capabilities and job creation, rather than catering only to those engaged in the individual projects.

The overall argument here is that opportunities to learn must be open and kept open and not only rely on temporary and fleeting learning spaces bounded to investment projects where key technologies and expertise are 'flown in' from abroad. The long-term role and linkages of these projects with local actors in the systems must be put in focus (Lema et al., 2018). However, this requires deliberate policy decisions and actions to make sure that skills upgrading and capability-building are institutionalised and grounded in local organisations. As the Adama II and LTWP cases show, this can be done in different ways.

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