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TOWARDS A CONCEPTUAL FRAMEWORK

Renewable electrification and sustainable industrialisation

Margrethe Holm Andersen and Rasmus Lema

Abstract

Renewable electrification is advancing at unprecedented rates across the developing world. The key purpose of this chapter is to define a conceptual framework for understanding and analysing how the up-take of renewable energy, i.e., the pathways and processes of electrification based on renewables, may support sustainable industrialisation. Our theoretical point of departure includes a combination of different types of innovation system theory, global value chain thinking, and project-based approaches with clear links to the literature about technology transfer understood as an interactive rather than a linear process. We suggest that renewable energy projects can be seen as embedded in different levels of innovation systems and global value chains combining what we refer to as 'the nested view'. Our conceptual framework furthermore suggests that intra- and inter-active learning processes related to renewable technologies may lead to accumulation of key capabilities that are in turn essential for the creation of new jobs and business opportunities (outcomes) and which may be useful for further sustainable industrialisation processes and development (long-term impact). The framework has been developed in connection with research on solar and wind energy projects in sub-Saharan Africa and how processes of electrification can be shaped to maximise co-benefits in terms of industrialisation that is green, inclusive, and durable. We argue that increased awareness about the implications of different pathways and the need for an engaged, deliberate learning approach taking into account the consequences of different choices for development of (innovative) capabilities is central for making use of the window of opportunity that the current increase in investments in renewable energy constitutes.

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Introduction

Until recently, industrialisation and (renewable) energy were mostly discussed as belonging to separate development policy domains. The connection between the two was one-way and was confined to the energy inputs needed to uphold manufacturing and services activities associated with industrialisation. This is no longer the case, however. In large developing countries like China and India, renewables are becoming part of the industrialisation strategy itself (Lema, Iizuka, and Walz, 2015; Mathews and Tan, 2013). Production of renewables creates manufacturing jobs, and their deployments generate highly skilled service employment. Of the almost 9.5 million jobs in sectors producing renewable energy worldwide, 60% are in Asia, and global renewable employment creation continues to shift towards Asia (IRENA, 2016). The Asian giants thus show a way of reframing industrialisation strategies based on renewables (Mathews, 2018).[1] The trend is currently continuing and spreading to other parts of the world (Mazzucato, 2018).

This chapter provides a framework for investigating the two overall research questions that shape this book: do renewable electrification efforts provide opportunities for sustainable industrialisation? If so, what are the opportunities and how can different renewable energy pathways be shaped in a way that supports the realisation of such opportunities?

In order to understand the potential of renewable electrification for sustainable industrialisation and the conditions required to turn such opportunities into reality, we will combine three analytical perspectives: Global Value Chains (GVCs), Innovation Systems thinking, and Project Focused Approaches. The intention here is not to make a broad and encompassing review of the literature in these fields, but rather to map out how the three different theoretical frameworks/approaches can be combined to analyse links between (renewable) electrification processes and sustainable industrialisation.

The connection between industrialisation and renewable energy, however, takes different forms in different parts of the developing world. Although the need for deployment of renewables is greatest in low and middle-income countries, the production and innovation capabilities required to integrate energy and industrial development strategies tend to be weak. Hence, it can be argued that building up innovation capabilities for renewable electrification constitutes an important missing link in ensuring the transition to a more sustainable development in such countries.

In order to explore this missing link, we investigate literature that may help us understand the linkages between learning, capabilities, and outcomes understood as capabilities (technological as well as organisational and project related). In other words, we want to understand how renewable electrification 'works'. On this basis, the chapter presents an analytical framework for analysing whether renewable electrification efforts provide opportunities for sustainable industrialisation, breaking down the capability-related co-benefits in the renewable electrification processes into three key elements: learning, development of capabilities, and the resulting (expected) outcomes. We also discuss connections between these elements – and how they may link up with sustainable industrialisation efforts. Finally, we conclude the chapter by providing some initial answers to the overall research questions and outline how the framework relates to subsequent chapters in the book.

Understanding renewable electrification processes

Renewable electrification is essentially equivalent to the production, deployment, and use of renewable energy. It involves several steps across three sets of chains: a production, a deployment chain, and a user chain. The production chain focuses on the production of core elements in renewable energy, such as wind turbines and solar photovoltaics (PV), and includes product engineering and design, component manufacturing, and equipment 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 relates to distribution and consumption of energy – and the technologies used to secure this, e.g., national electricity grids, systems for distribution energy in mini-grids, and technologies such as mobile money used to support the distribution of energy through small-scale solar PV systems for individual households.

In each step of these chains, there are multiple actors involved (Lema, Rabellotti, and Sampath, 2018b) ranging 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 of renewable energy systems to the project site, preparing the project site, and connecting the energy producing systems to national grids or mini-grids. Different energy providers (public, community based, or private) are involved in delivery of the electricity to end users (institutions, firms, households) through connections to the national grid, mini-grids, or indeed through small solar PV systems targeting individual households.

The interactions between the different actors at the different steps of the value chains differ and may – as we will see in the empirical examples provided in this book – provide more or less efficient and effective possibilities for learning and building different types of capabilities. Such options are also influenced by the conditions under which firms produce and deploy different types of renewable energy technologies, including international policy regimes and national policies, strategies, rules, and regulations. The differences in the value chains also influence the extent to which they may contribute to more inclusive innovation and development pathways.

Another issue critical for understanding how renewable energy projects work is the size of the technology, which is typically also associated with the form or shape of the technology in use (Hansen et al., 2018): basically, there are three models or pathways:

1. *Large-scale grid-connected renewable energy projects*: based, for example, on solar or wind energy and requires extension of grids into areas that currently do not have access.
2. *Mini-grids using renewable energy that are not connected to the national grid*: self-contained grids established in rural villages, using micro hydro, solar, and micro wind – or a mix of these.
3. *Off-grid approach*: electricity generation tied to the individual household or factory – typically solar rooftop solutions or pico-solar systems.

The three different pathways provide different opportunities not least for engaging local firms and actors. It is also evident that electrification in low and lower-middle-income countries, e.g., in sub-Saharan Africa, will involve all three pathways. But important questions remain about the balance between the various pathways, what options they provide for learning and capability-building – and how they can be set up to maximise inclusiveness and economic development (Lema et al., 2018b; Leach et al., 2010). One underlying issue in this chapter is to create the foundation for comparing the main pathways and to study capability-development dynamics within them as well as the implication of these dynamics for fostering broader sustainable industrialisation.

Theoretical starting points

The *global value chain approach* focuses on the way in which value is added to at different stages of the production process and how these are located in different countries. It has been used to analyse successful catching up, e.g., of Asian economies (Gereffi and Korzeniewicz, 1994), but also – more recently – in critical analyses of the linkages between global value chains and sustainability governance (Ponte, 2019). The *national innovation system* concept was introduced by Lundvall (1985a, b) and further elaborated in Lundvall (1992) and Lundvall et al. (2002). It has been used to understand the systemic nature of innovation in the context of economic development (Lundvall et al., 2009). The two concepts of global value chains and national innovation systems have developed in parallel and both are increasingly used to analyse economic development (Bolwig et al., 2010; Ponte and Ewert, 2009). They are also increasingly being linked to the global challenges of climate change and analyses of how different actors may or may not help solve such challenges (Ponte, 2019; Mazzucato, 2018).

The innovation system perspective points to the need to establish and develop domestic linkages while the value chain perspective is concerned with alignment of and power relationships between global lead firms and domestic actors.

We see it as a promising line of research to combine them. Although initial theoretical attempts have been made in this regard (Pietrobelli and Rabellotti, 2011; Lema, Rabellotti, and Sampath, 2018a), few prior studies have brought these approaches together in an operational way for empirical analysis.[2] There is, therefore, a need to develop a framework that can facilitate this – and a big need for investigating further and in a more disaggregated manner, the way interactions between the global value chains and the local and national innovation systems interact.

The third element of the analytical framework presented in this chapter and used to different extents by authors of the specific chapters in the book is the project-focused approaches. A focus on projects and the way they are organised is key to an improved understanding of how renewable electrification processes play out on the ground, what learning takes place in different contexts, and what capabilities are (or are not) generated (see e.g., Hanlin and Okemwa, this volume).

Innovation systems and renewable electrification

The innovation systems approach often analyses national systems of production and innovation to explain variations in innovation performance across countries. Scholars in the field emphasise the role of different types of learning and suggest that both intra- and interactive learning are key to increasing innovation performance (Lundvall, 1985a; Jensen et al., 2007). Analyses of national systems of innovation can help to identify 'system failures' that lead to less advantageous outcomes. In this chapter we do not seek to compare innovation systems in sub-Saharan Africa and more advanced nations that can be considered 'lead markets' in wind (e.g., Denmark) and solar PV (e.g., Germany and China). We rather focus on what opportunities, if any, renewable energy projects and different pathways for renewable electrification may entail for sustainable industrialisation *within* sub-Saharan Africa. Our analysis is concerned with broader issues and implications of innovation, including the choice of technologies and distribution of benefits from different types of innovations (Stirling, A, 2009; STEPS, 2010), but with a particular focus on these issues based on an analysis of renewable energy projects in the region (cf. also Ockwell and Byrne, 2016).

The focus on solar and wind energy sectors makes the 'sectoral system' approach relevant since it has specialised in sectoral comparisons (e.g., Malerba and Nelson, 2011). The sectoral approach needs to be combined with insights from work that has focused on 'system building' in the case of developing innovation systems (Lundvall, 2007). Research has also shown that the sectoral system approach can benefit from the introduction of a more disaggregated perspective. This has led to the introduction of an approach where a distinction is made between both different types of (sub) technologies and different sizes of projects (large, grid-connected wind, and solar power plants vs. wind or solar powered mini-grids) (Hansen et al., 2018; Hansen et al., this volume). Finally, research using the Technological Innovation System thinking as a framework (Kebede, Mitsufuji, and Islam, 2015; Wandera, 2018) indicates that this framework can also be used to shed light on issues and missing links in the up-take of renewable energy in sub-Saharan Africa.

Stronger innovation systems can facilitate enhanced up-take and use of new technologies, including renewables (Lema, Rabellotti, and Sampath, 2018b), but they do not necessarily develop by themselves.

At the national level there are numerous relevant policy domains which cross across different renewable energy sectors, not least those concerned with feed-in tariffs, electricity generation licences and permits, etc. There are cross-ministry development plans which (in principle) synchronise regulation across ministries. There are state policy and regulatory bodies, utilities, transmission systems operators, and education systems. In the private sector there are local equipment manufacturers and assemblers, wholesale importers and distributors, logistics firms, sectoral trade organisations, and many more. There are vertical value chain links as well as horizontal links within the systems that provide various types of inputs to the electrification processes.

In subsequent sections of this chapter we draw in an eclectic way on various types of innovation systems thinking. We find that both national, sectoral, and technology specific innovation systems thinking may help create a better understanding of processes required to increase up-take of renewables, such as solar and wind. More importantly, different systems-traditions have different strength and weaknesses. For example, the Technological Innovation Systems (TIS) approach has developed a static but easily applicable framework for identifying inducing and blocking mechanisms for technological development and diffusion. This has often been used to study renewable energy in Europe. However, it has also been used in studies of renewable energy diffusion in the African context (Kebede and Mitsufuji, 2017; Wandera, 2018).

In summary, we find that various approaches to innovation systems thinking (National Innovation Systems [NIS], Sectoral Innovation Systems [SIS], and TIS) are complementary and can be used to inform our conceptual framework for analysing the development of capabilities through renewable electrification activities and projects – capabilities which may in turn have potential for development of sustainable industrialisation more generally.

Global value chains

The Global Value Chain (GVC) approach typically analyses relationships between lead firms from advanced economies and suppliers in developing economies. From the developing country perspective, it is typically about 'learning from exporting' (upgrading in GVCs). Our focus is the reverse: 'learning from importing' renewable energy products and services. In this context we are concerned with governance structures and knowledge exchanges between buyers and lead firm suppliers in more advanced economies. There are clear connections to literature on technology transfer (Bell, 2007, 2012; Ockwell and Mallet, 2013) and to more recent work focused on technology transfer and local capability formation (Lema, Rabellotti, and Sampath, 2018b; Hansen et al., this volume).

Global value chain thinking (Gereffi, 2014; Humphrey and Schmitz, 2002; Kaplinsky and Morris, 2000) may contribute to a better understanding of learning opportunities in renewable energy projects and activities (low carbon development) in various ways. First, it moves beyond a narrow focus on technology producers (exporters) and users (importers) and thereby helps map out the many actors in the value chains; their role in technological transfer processes and in interactive learning related to development of local capabilities required both for renewable energy and sustainable industrialisation in a broader perspective. Second, the global value chain thinking may help enhance our understanding of issues related to power relations in technology transfer and capability development – and not least the role of powerful lead firms in specific (global) value chains.

The global level governance structures and knowledge exchanges include such domains as trade regulation such as World Trade Organisation (WTO), global standards by the International Organisation for Standards (ISO), and institutional infrastructures concerned with the Technology Mechanism linked to the UN Climate Change process (and, before it, the Clean Development Mechanism (CDM)) within the United Nations Framework Convention on Climate Change (UNFCCC). Global level governance structures and knowledge exchanges also include large equipment producers (think Vestas and Yingli Solar) and project developers, and investment funds, consultancy firms, NGOs, and providers of overseas development assistance. At the global level there are, not least, inter-national linkages formed 'vertically' between producers, project developers, financers, and consultancies in China and Europe and renewable electrification firms/organisation in, for instance, Kenya.

The various networks and linkages established form opportunities for learning, but they may also limit learning opportunities for local stakeholders, for instance when a lead company does not want to share key knowledge related to the technology they are bringing along. In other words, the chain governance influences the possibilities for extracting more economic value through learning in the South (Lema, Rabellotti, and Sampath, 2018b, p. 5). The technology transfer chains linked to e.g., renewable energy, are in a way *reverse value chains* that may (or may not, depending on how organised) help develop local capabilities.

Opportunities for learning exist both in the production, deployment, and use steps of the value chain (cf. Figure 2.1 above) and may be driven both by actors from the North and the South. Empirically, however, there is very little evidence of development of local capability formation and industrial development in renewable energy industries in sub-Saharan Africa irrespective of where the technology comes from (Lema, Rabellotti, and Sampath, 2018b; Bellini, 2017) and so far most of the outcomes in terms of jobs and income opportunities

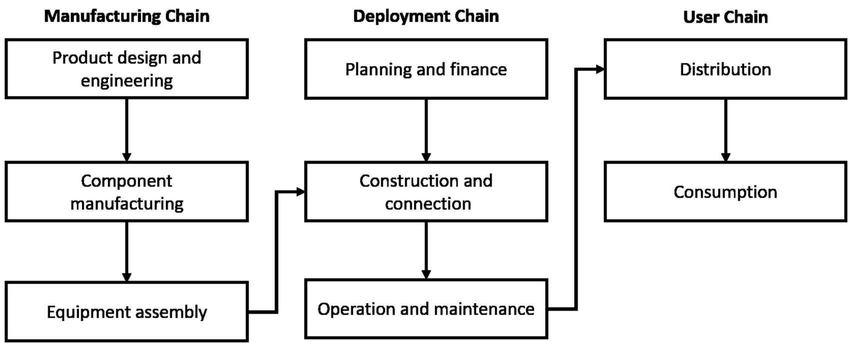

FIGURE 2.1 Steps in the production, deployment and use of renewable energy. Source: drawing based on Lema, Quadros, and Schmitz (2015b) and Lema et al. (2016).

linked to renewable energy projects seem to be linked to the deployment steps, i.e., installation (Lema, Rabellotti, and Sampath, 2018b; Hansen et al., 2018). The capability-building found in this part of the value chains is less 'hardware' oriented than in the manufacturing part of the value chain as it is often focused on servicing and involves operating skills and know-how. But evidently, such skills and capabilities are key to ensuring durable and sustainable use of the new technologies installed and avoid a whole new generation of large (and small) white elephants in the form of renewable energy facilities that end up not functioning.

In short, we consider the value chain approach fruitful for a more systematic investigation of learning opportunities and capability development in renewable electrification (RE) value chains as well as for revealing opportunities for sustainable industrialisation potentially arising from renewable electrification projects. We also find that a more explicit focus on opportunities related to the RE value chains may help identify critical learning and capability gaps that need to be addressed – and which are in turn critical for the required strengthening of local and national-sectoral innovation systems.

Project-focused approaches

The innovation system and value chains approaches are complementary since they emphasise different aspects of economic interaction and because they focus on different units of analysis (Jurowetzki, Lema, and Lundvall, 2018). They are helpful in guiding comprehensive analyses of the circumstances and relationships that will structure the provision of sustainable energy. In particular, they also combine when one seeks to address *user-producer interaction* (as will be discussed below).

But in a certain respect they are both insufficient – individually and when combined – i.e., in terms of scope or unit of analysis. This is because *renewable* *electrification is essentially a project-based activity*. It implies that a project-lens can help to examine specific cases of renewable energy deployment and trace interactions within the project and beyond it (nationally and globally).

There is a wealth of literature to draw upon, including literature on project management and innovation (Brady and Hobday, 2011). Most of this literature is, however, focused on advanced economies and/or very large-scale projects. Still, there is an innovation and development literature on design and engineering which seems relevant since it has explicit connections to both national systems and global value chains literature. This includes unpublished work by Abdelkadar Djeflat and colleagues on the need to develop design engineering capacity and innovation in North Africa[3] and the pioneering work by Bell (2007) on design and engineering in infrastructure and industrial sectors. The key point here is that there are different stages in all projects, ranging from project development over procurement or manufacturing of the technologies to installation, operation, and maintenance. And that each of these steps includes opportunities for learning.

Bell (2007) distinguishes between (a) owner-driven, (b) contractor-driven, or (c) jointly driven project structures. Owner-driven project modes – where the owner-operator (e.g., the Kenya Electricity Generating Company PLC, which is the leading electric power generating company in East Africa) takes charge of coordination and execution – were dominant until about 20 years ago. This is no longer the case because of increasing outsourcing of design and engineering activities to competent contractors, many of which are multinational firms. Owner-driven models might still, however, be commonplace in *large and grid-connected* facilities where the owner is a utility or a private investor. The Lake Turkana Wind Power Project in Kenya seems to follow such an owner-driven model. Contractor-driven models may be prevalent in case of *mini-grids* where there is community-based ownership or smaller private ownership. Whether this is the case is a question for empirical analysis. In both cases there is a substantial element of involvement of Multi National Corporations (MNC), even if these are sometimes small design and engineering firms, e.g., small and medium solar system providers from Germany. Jointly managed projects involve extensive involvement of both owners and specialist contractors. The Garissa Solar Project may be seen as an example of this in the sense that the project is owned by the Kenyan Rural Electrification and Renewable Energy Cooperation (REREC), but has been developed and installed by specialist contractors from China with some inputs being provided by local suppliers.

There is also a literature on 'strategic niche management' (Geels, 2002) which may be relevant. From a science and technology systems perspective, this literature looks at how small technological niches emerge and grow to influence overall technological trajectories. Authors from this tradition have begun investigating 'sustainability experiments' (projects) as niches in developing countries (Berkhout et al., 2010). Some of this literature has been specifically concerned with rural electrification in developing countries (Drinkwaard, Kirkels, and

Romijn, 2010; Romijn, Raven, and de Visser, 2010). Such literature seems particularly useful as a starting point for thinking about the relationship between projects and larger sectoral systems.

At the project level there are contracts specifying agreed rules, and roadmaps and project design documents that stipulate who does what and how. The project comprises the various actors involved in installing and operating wind or solar PV technology, including principally firms and other actors involved in installation and operation of renewable energy projects. These may include owners, project development firms, equipment producers, operators, maintenance firms, etc. Production and consumption of electricity is physically co-located in the case of mini-grids, but it is separated in the case of grid-connected facilities. In other words, end users are not necessarily an 'actor' in these projects.

While innovation systems linkages may be 'durably' and slowly evolving, interactions in projects are often more 'temporal' and/or 'sequential': a project is typically time-bound and linked to the development of a new product or service e.g., a power plant run by either hydro-power, solar, or wind. When a project is completed, a large number of actors involved will typically move on to a new project. Projects typically cover the full project cycle from initial idea and design through construction and may or may not extend into operation and management phase. This poses particular challenges in countries where general technical and organisational capabilities may not be sufficiently developed. For instance, there is often particularly intense interaction between project participants during the phase of project design, engineering, and installation, while interaction during operation (and maintenance) depends to a large extent on whether service contracts are entered into and whether suppliers of energy sources have a responsibility to assist in making sure the projects remain operational. Different actors may focus on becoming good in one particular part of the project cycle or might span across several different parts of the project cycle. This is also linked to who drives the project (contractor or operator).

A nested view

Figure 2.2 below seeks to provide a simple illustration of how the three levels of analysis can be combined in a 'nested view'. Economic geographers working on global production networks (Henderson et al., 2002) have proposed such a view, but the model is here adapted to the specific topic of concern, i.e., electrification processes in low and lower-middle-income countries.

Nested view models have typically derived from analyses of producer-driven (see below) value chains manufacturing and integrating modular consumer goods such as automobiles and electronics (see e.g., Coe, Dickens, and Hess, 2008; Sturgeon, Van Biesebroeck, and Gereffi, 2008). They have therefore tended to focus primarily on the production landscape, while largely by-passing the interface with consumption (the individual or collective consumer). The value-added chains, which are analysed, tend to start from suppliers in developing countries,

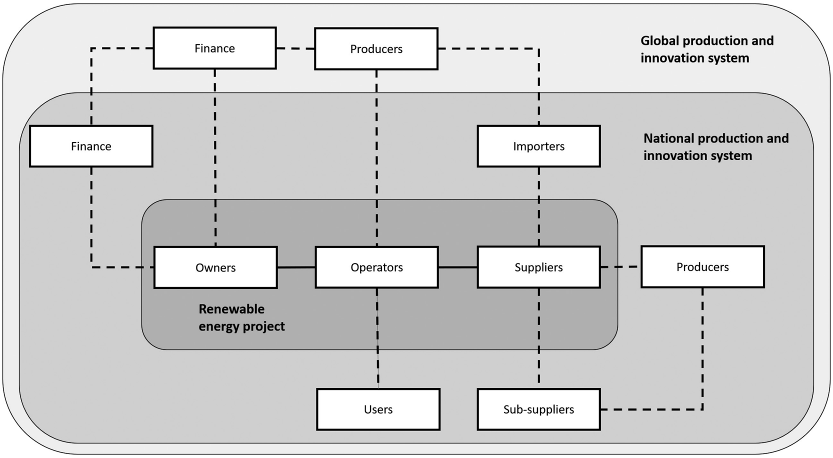

FIGURE 2.2 Nested view. Source: authors.

providing inputs for large lead firms which cater for consumers globally, not least in advanced economies.

The renewable electrification setting is markedly different. The purpose here is therefore to draw only loosely on the notions proposed by Coe, Dicken, and Hess (2008) and others to conceptualise nested relationships in sectors, which are essentially concerned with the provision of (energy) services in the context of renewable electrification in developing countries. This means that the renewable energy project, including the interface with professional or collective consumers (e.g., utilities, big firms or institutions, local communities), constitutes the 'micro level' in the nested view adopted here. It situates renewable energy projects within the national-sectoral and global context.

This view thus comprises three main levels of analysis:

- Global solar/wind industry and governance mechanisms (global level)
- National-sectoral system of innovation production (national level)
- Renewable energy project (project level)

The task is to examine each level both in separate studies focusing on key actors and institutions in and around (a) global value chains, (b) national-sectoral innovation systems, and (c) critical projects, and to trace and examine the interactions between them.

By doing so we aim to explore how learning and capability-building is related to each of the three levels. One key proposition is that the governance of the global value chains (how they are organised, who dominates which parts of the chain, and what power relations are embedded in these) impact the types of learning and capability-building that takes place or may take place. Some MNCs may for instance give high priority to training of local staff because it helps them reduce costs and strengthens their business model, while other international actors may be more hesitant to share knowledge with local actors. Similarly, international policies and financing mechanisms (think e.g., bilateral and regional funding agencies such as the Nordic Investment Fund and the Danish Fund for Investment in Developing Countries) may for instance encourage local content and local learning and capability-building to different degrees and thereby influence the extent to which local actors (firms, knowledge institutions) are able to 'learn from importing'.

The characteristics of the national-sectoral systems of innovation and the actors in these, including policy makers, the financing system, importers, and other local actors, also influence the extent to which learning and capability-building takes place. National energy policies may, for instance, encourage local contents and learning – or may not be focused on such opportunities at all. Similarly, if local knowledge institutions (e.g., vocational training centres and universities) provide local technicians and engineers with a solid level of basic knowledge, e.g., in wiring or other fields, this can enhance possibilities that local staff can benefit from interaction with external actors and enhance their capabilities. A diverse range of pathways (small/large and using different sources of energy) may thus help foster more inclusive development.

Towards an analytical framework

A key issue in this chapter is the current trends in renewable energy production (notably solar and wind), the pathways linked to these trends, and in particular how different sources of technology and their associated characteristics influence possibilities for local competence-building and technology adaptation. These issues are crucial for strategies aimed at using green technologies for sustainable industrialisation and transition in a broad range of low and lower-middle-income countries in sub-Saharan Africa and beyond. They are also crucial because different innovation pathways towards electrification represent different directions with implications for distribution (winners/losers) and diversity (ensuring that multiple options are considered). We argue that increased awareness about the implications of different pathways and the need for an engaged, deliberate learning approach taking into account the consequences of different choices for development of (innovative) capabilities is central.

The purpose of this section is to outline a basic analytical framework for analysing these issues. The framework – presented in Figure 2.3 below – breaks down the renewable electrification process into three key elements: learning, development of capabilities, and the resulting (expected) outcomes – with long-term impact in the form of sustainable industrialisation and other socio-economic benefits resulting from this process. In the following, we will elaborate on each of these three elements considered key for the 'framing' of our analysis of how the renewable electrification process plays out in the countries we are dealing with in the empirical analyses conducted throughout this book.

A basic analytical framework

Our basic analytical framework (Figure 2.3 below) is essentially a theory of change prepared on the basis of the combined reading of the literature discussed above. It is based on the assumption that interactive (in projects, national innovation systems, and in global value chains) as well as intra-active (or organisational) learning (in firms but also in other organisations) are vital to the development of (technological) capabilities. The development of enhanced technological capabilities is in turn expected to lead to outcomes such as increased employment, local business opportunities, and content of contracts, new firms, and more 'inclusive' and relevant electrification processes.

The long-term impact of such outcomes is expected to include increased access to electricity, increased energy security, and related socio-economic benefits such as improved health, increased education levels, and enhanced incomes. Sustainable industrialisation, i.e., industrialisation that is more durable, greener, and more inclusive, will also come about as a long-term impact if renewable electrification processes are properly managed and made use of.

Obviously, there is no automatic link between each of these elements, and a number of factors not made explicit in the model will influence the extent to which the outcomes and long-term impact are actually achieved. Such factors may have to do with the willingness of foreign firms to share knowledge with local actors and with local actors' existing levels of education and capabilities to take up new jobs generated as RE projects are implemented in a country.

Even so, the underlying idea of the basic analytical framework is that understanding the way inter- and intra-active learning unfolds in specific renewable

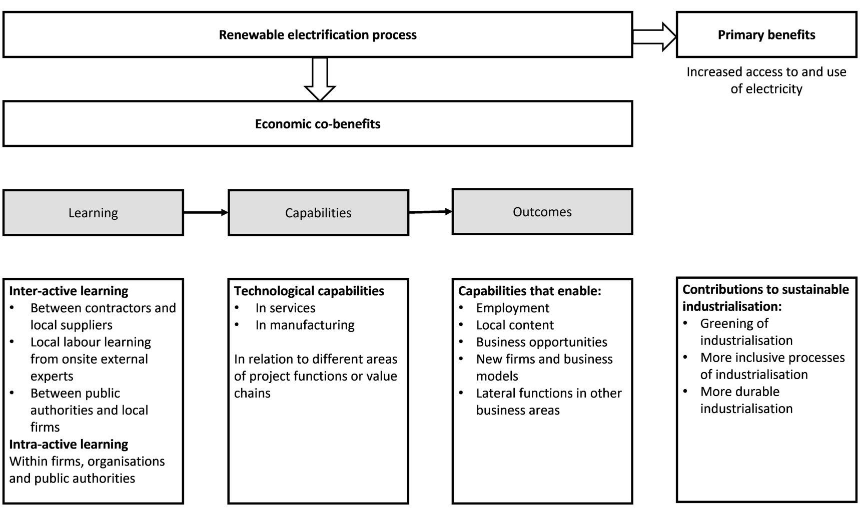

FIGURE 2.3 Renewable electrification processes: learning, capabilities, and outcomes. Source: authors.

energy projects, national innovation systems, and in specific sectoral value chains forming part of the global value chains in solar and wind is key to understanding which capabilities are developed.

Likewise, it is an underlying idea of the framework that developing (technological) capabilities is key to ensuring desired outcomes in the form of employment, local content, business opportunities, and establishment of new firms as well as to more 'inclusive' and relevant electrification processes. Our primary focus in the chapter is on the two first boxes of the model dealing with learning and building (technological) capabilities.

Understanding what capabilities are available in a specific country and the learning processes and processes linked to building different forms of capabilities may also help us understand why some capabilities are not created and what could be done to facilitate the generation of these. In this book the question of capability development is reviewed on the basis of both quantitative surveys and more qualitative work (e.g., case studies of critical projects).

Finally, feedback mechanisms are important: as local staff, firms, projects, and knowledge institutions as well as government bodies build up knowledge in RE, there is a possibility that they become better equipped to take advantage of new knowledge and technologies brought into a particular country e.g., by foreign firms. Virtuous circles may be generated that help increase the stock of capabilities and hence the absorption capacity.

Learning

Learning is a fundamental prerequisite for sustainable economic growth and development (Lema, Rabellotti, and Sampath, 2018b; Cimoli, Dosi, and Stiglitz, 2009). Learning is understood here as the accumulation of relevant capabilities; we are informed by the increasing body of literature which emphasises the importance of local production and innovation capabilities for effective low carbon development. Figure 2.3 illustrates that there are many learning mechanisms – i.e., ways in which learning can take place. Some of these are intra-active (understood as internal to the firm) and some of these are interactive (i.e., include interaction with actors outside the firm).

Inside firms, learning may take place through on-the-job training, through in-house training courses or seminars, or through internal knowledge exchange platforms (intranet), etc. The learning may be more or less formalised – and often will also include use of knowledge from outside e.g., in the form of presentations of new research. In other words, intra- and interactive learning are often combined, and research evidence suggests that the most innovative firms are those that are able to combine practical and interactive learning (Doing-Using-Interacting or DUI) with more scientific insights (Science, Technology, and Innovation or STI) (Jensen et al., 2007). Without neglecting the importance of intra-active learning, the analytical framework developed in this chapter places particular emphasis on inter-active learning understood as learning in interaction with others at three different levels: renewable energy projects (often involving several or even many different firms), the national-sectoral innovation systems (with particular emphasis on solar and wind), and the global value chains in solar and wind as they unfold, develop, and relate to the context experienced in Kenya and other low and lower-middle income countries.

The learning taking place may be more or less strongly tied to specific sectoral innovation systems and to the development of specific technologies, such as e.g., solar PV (see Karjalainen and Byrne, this volume). As such, the degree to which the learning is specific for a sector has implications for subsequent parts of the theory of change, e.g., the extent to which lateral transfer and reuse of capabilities occurs.

What types of learning are particularly important to ensure sustainable industrialisation benefits from renewable electrification? This is a question for empirical research, but the following types (or arenas) of interactive learning have been identified in the extant literature (Lema, Rabellotti, and Sampath, 2018b):

Interactive learning between contractors and local suppliers

Service providers and local firms play a key role in the RE value chains and the importance of their interactions with their clients, especially the main contractor of a wind or solar PV project; this main contractor is essentially a professional user (as opposed to an end-user; see Lundvall, 1985a, b). Professional users have more defined needs in terms of what products and services they require and as such, a good level of interaction – which focuses on learning the needs and wants of the other – between suppliers and the main contractor will ensure a more efficient project and should reduce delays. This is important on both sides, not only for building up competences of local suppliers and their reputation in the market, but also reducing the 'lock-in' of dominant sourcing policies of lead firms in a project setting (Hanlin and Hanlin, 2012). Both are needed if strong backward and forward linkages are to be created within GVCs. These need to be encouraged by governments so as to create the development of dynamic capabilities in firms and through these a stronger more diversified economic base (Morris, Kaplinsky, and Kaplan, 2012; Lundvall and Lema, 2016).

In a situation where learning takes place in a series of single projects – each with a new constellation of users and producers – a major issue is what institutional setting allows for an accumulation of capabilities. Firms that take on the role of coordinating large projects such as the Lake Turkana Wind Power Project (LTWP) in Kenya e.g., through an Engineering, Procurement, Construction, and Management (EPCM) contract (Hanlin and Okemwa, this volume) are one possible way of accumulating knowledge and capabilities, in particular if they are able to successfully bid for a series of projects and retain (key) staff. But small organisations with civil engineering competences in addition to government entities may also play a role here if they have an explicit focus on fostering accumulation and dissemination of learning.

Local labour learning to 'use' the new installations – operating and maintaining

As indicated above, less codified knowledge and experiential learning that comes through 'doing, using and interacting' (Jensen et al., 2007) is an important (but often not well recognised) way of learning. Local staff need to understand how different parts of the technology within a solar PV or wind project work and to be provided with the opportunity to take over the 'operations and maintenance' part of the project lifecycle – getting some of the practical experience required to maintain the systems. Requirements for increased local content in new small or large renewable energy projects being established in a country (e.g., LTWP in Kenya or the wide range of solar energy projects in e.g., Tanzania and Kenya) may increase such options. It requires, however, not just a new mindset from lead firms in the projects, but also government support of the relevant training and education needed to ensure there are technicians and/or engineers available locally to conduct such work. In some cases, lead firms (whether large or small) may organise training both on-site and in other countries to ensure local staff develop the knowledge required for operating and maintaining the systems installed. They are more likely to do so, if they can reduce costs by hiring more staff locally while keeping in place systems that ensure the necessary quality control. In other cases, lead firms may prefer to bring in and use their own staff (Hansen, 2019).

Public authorities and private companies learning to manage major projects

Public authorities are key in terms of regulating and supporting renewable electrification through promotion of training schemes etc. However, sometimes governments are also *de facto* the 'lead firms' in projects: commissioning, managing, and/or running RE projects once construction is completed. This requires a change in mindset for government departments as they need to start behaving like lead firms and act in a more commercially oriented manner than might otherwise be the case.[4] Public authority entities may very well gain from liaison with foreign engineering firms and knowledge institutions such as universities abroad in learning how to manage projects. As noted by Hanlin and Okemwa (this volume) private firms in Kenya (and the region at large) also need to improve their capabilities in project management as such capabilities are vital to the successful implementation of RE projects and may also be helpful in ensuring that opportunities for sustainable industrialisation arising from renewable electrification processes are realised because such capabilities are possible to reuse in other large infrastructure projects.

Finally, there are also a range of international attempts to create new and more interactive ways of learning about green solutions. Examples include e.g., C40 which involves a range of major cities in the world (www.c40.org) and the P4G[5] which has been established to help bring green growth policies into practice and may provide important opportunities for cross-country learning between public authorities, the private sector, and civil society through the establishment and interaction of national platforms.

Capabilities

A capability can be defined in the simplest form as 'having the capacity (resources, skills/competences, and knowledge) to carry out a task'. Capabilities can be locally defined as domestic as opposed to global but can also refer to capabilities at the sub-national (county, village) level. Capabilities – and in particular technological capabilities – are key to ensuring development of a country's industrial levels and also to its ability to learn, absorb, and make use of technologies developed elsewhere.

There are many different ways of understanding, categorising, and analysing technological capabilities. Figure 2.3 highlights that the stock of capabilities in service and manufacturing is particularly important for renewable energy and understanding the opportunities that projects in this field generate for sustainable industrialisation in low and lower-middle-income countries. The capabilities may relate to different areas of project functions and/or to different value chains.

With the rapid development of renewable energy technologies elsewhere in the world, development of capabilities and absorption capacity (Cohen and Levinthal, 1990) is key, if sub-Saharan Africa is to reap the full benefits from these which would mean achieving higher degrees of electrification through integration of renewable energy and successfully undergoing transformation processes leading to inclusive and sustainable industrialisation. Capabilities are important not just in the manufacturing part of the value chain – but also in the deployment and post-deployment steps.

The capabilities needed and available in the manufacturing, deployment, and user chains are embodied in people who have the skills needed to conduct different activities at different stages of manufacturing, deployment, and use chains. But they are also embodied in equipment and other physical technologies. They are also the result of combined activity at an organisational level. They are about practitioners in industry but also about policy skills, knowledge, and learning.

Our key point is that capabilities are not just about developing new technologies or new components in renewable energy. It is also (and maybe even more importantly) about how new technologies and new components in renewable energy systems are made use of in practice – through projects of different sizes and within different sub-sectors such as e.g., small vs. large wind and small vs. large solar.

This book is particularly interested in innovation capabilities and for this we draw on the work of Bell (Bell and Pavit, 1995; Bell, 2009; Bell and Figueiredo, 2012), Lall (1994, 1998), and others (c.f. Archibugi and Coco, 2005; Vidican, 2012; Watson et al., 2015; Baker and Sovacool, 2017; Hansen and Ockwell, 2014). A few of these have discussed innovation capabilities in the context of renewable energy technology manufacturing, deployment, and use. Based on their work, we can develop a typology of capabilities needed across the manufacturing, deployment, and use chains.

The different types of capabilities can be described as follows:

Physical technologies

Hardware that is bought for use by the firm, licensed or bought into the firm through a sub-contract, joint venture, or other partnership types. Examples of these technologies include cutting machines or furnaces during manufacturing; cranes or welding machines during deployment; and electricity meters or inverters during use.

Skills and knowledge/human capital

The skills and knowledge can be embodied in people i.e., through employing new staff or bringing into a project a consultant where the skills are not available within staff who are currently working on the project. It can also refer to sending staff on training to acquire the knowledge and skills needed. Related to this last point, this knowledge can also be codified in training manuals or instruction manuals that come with new equipment. However, skills and knowledge can also be learnt on the job over time because some skills and some types of knowledge are difficult to easily teach or codify into a training manual. Here we are not just referring to technical skills, i.e., in how to manufacture a turbine part or build a solar plant. We are also referring to a wider set of skills and knowledge that are needed throughout the renewable electrification project lifecycle: in how to finance and manage projects, in understanding and promoting conducive and supportive regulatory environments, etc.

Organisational change and linkages

Lall (1994, 1998) and Bell (2009) both recognised the importance of not only skills and knowledge embodied in individual people or technologies but also the importance of a broader, firm level understanding of how everything needs to fit together. This is very similar to the idea of 'core competences' (Hamel and Prahaled, 1990) or the idea that firms need to consider developing a unique set of abilities that gives them a competitive advantage over their competitors. However, Lall and Bell also focus on the importance of understanding the connections needed between different elements of the system of actors that are responsible for the successful completion of the various chains e.g., interfirm linkages and broader systems linkages. Lall (1992) notes the importance of having the right training institutions available to support local businesses and facilitatory regulatory systems – the right set of incentives and systems structures to support interfirm linkages.

Finally, as noted above, capabilities of different kinds are also very important in the public sector which solicits projects and regulates the policy domain. Many of the capabilities required in the public sector differ from those required in for instance firms producing key renewable energy technologies, because the role of the public sector in renewable electrification and sustainable industrialisation processes is different, but to ensure the restructuring of economic activities in this direction is not a small task and requires that all actors play their role. We return to the role of the public sector and policy makers in the last part of the book (Kingiri and Okemwa, 2022; this volume and Lema et al., 2022; this volume).

Outcomes

We define the outcomes of renewable electrification processes as benefits and/or resultant consequences of these processes including *employment (jobs)*, *local content*, *business opportunities*, and *new firms*. As such, they are closely linked to the capabilities that are developed or may be developed due to involvement in renewable electrification projects and processes. Emphasis is on outcomes in the form of capabilities generated through involvement in renewable energy projects and the possibilities these capabilities generate for supporting broader strategies for sustainable industrialisation and – in a broader perspective – also for issues related to questions of justice (cf. also discussions in Scoones et al., 2015).

It is an important hypothesis of this chapter (and the book as a whole), that renewable energy processes can be leveraged to result in these outcomes – but also that achieving these outcomes is not an automatic process. On the contrary, whether the outcomes are realised depends on a number of factors, such as the characteristics of the technologies introduced, the strategy of the supplying firm, the absorption capacity of the national-sectoral innovation system (including local firms), and the project specific features relating to different renewable energy projects. It may also depend on public policies such as policies promoting local contents in renewable energy projects and processes (see Gregersen and Gregersen, 2022; this volume and Kingiri and Okemwa, 2022; this volume).

Renewable electrification may result in increased employment and training opportunities in connection with e.g., manufacturing, installation, and maintenance of energy producing entities, such as wind- or solar-powered mini-grids or grid-connected wind- or solar-power plants. The amount of employment generated can be difficult to measure and may differ according to both the shape and the size of the technology in question (Hansen et al., 2018). The type of employment (and training) opportunities may also be influenced by introduction of renewable energy projects and hence attempts to document such changes are important.

New business opportunities and entirely new firms may emerge in connection with renewable electrification processes. New business opportunities (and firms) may for instance relate to the rapid development of solar pico-systems and solar home systems in recent years (Hansen et al., 2018). Existing and new firms may also include project development firms engaged in the preparation of renewable energy projects or firms involved in manufacturing, installation, and/or operation and maintenance. In the case of Kenya, there are also indications that some firms previously engaged in small wind energy have shifted their focus to solar energy (Hansen et al., 2018) or have become engaged in various types of hybrid systems.

Benefits and outcomes related to local content are related closely to government policies and whether government puts demands on foreign investors and companies to involve local companies or institutions when embarking on renewable energy projects in low and lower-middle income countries. Such demands may relate both to local engagement in project preparations (e.g., site preparation, access roads, and establishment of on-site services near large solar- or wind-power plants) and in the actual installation and operation and maintenance of the plants. Demands may be more or less specific and may have different levels of impact on local capabilities. If local companies succeed in getting involved in large-scale projects, they may obtain knowledge that can be referred to in future bids.

Measuring the outcomes of renewable electrification processes and the extent to which an additional number of jobs or new companies relate directly to these (and not to other factors) is a challenge. Statistical data, surveys, and in-depth case studies of critical projects can be used to gain insights into this, but often a combination of methods and a high level of triangulation between the various types of information is required.

Terrapon-Pfaff et al. (2014) also found that expectations related to productive uses and business development following on from renewable energy projects have been overestimated and that 'project design must explicitly incorporate activities that go beyond energy access in order for these to become an outcome of the project'. In this context, it is important to distinguish between direct outcomes in the form of employment, training, business opportunities, and local content directly related to the development and implementation/deployment of renewable energy projects on the one hand and indirect outcomes/effects of having access to electricity on the other. We are, in this chapter, primarily interested in the direct outcomes as explained above.

Finally, it should be mentioned that there are also potentially negative outcomes related to renewable electrification processes. Large-scale wind-projects such as the Lake Turkana Wind Power Project (LWTP) may for instance increase the demand for well-educated and experienced engineers to take over on operation and maintenance and thereby 'crowd out' other renewable energy projects or organisations unless mitigating efforts are made to increase number of engineers trained more generally and with the specific skills required. In some cases, large-scale projects also tend to overlook the requirements in the local communities (e.g., local communities may not get access to the electricity produced in Lake Turkana, but continue to rely on traditional sources of energy).

Concluding remarks

This chapter set out to investigate two overall research questions that shape this book: do renewable electrification efforts provide opportunities for sustainable industrialisation? If so, what are they and what are the conditions which may turn such opportunities into reality?

In the nested view (Figure 2.2) we illustrated how renewable energy projects (implemented and functioning in different localities) are embedded in both national-sectoral and technological innovation systems, the latter of which are often global in nature and forming the basis for global value chains focused e.g., on solar PV or wind energy. Learning spaces and opportunities for building capabilities are located at different levels – but they are also linked to different stages in the value chain: some relate to the production of core technologies such as solar PV and wind turbines, while others relate to the deployment and use of these (Figure 2.1).

We subsequently proposed that different types of interactive learning take place in firms, in sectoral and national innovation systems, and in the global value chains and complement intra-active learning within firms and organisations engaged in renewable energy activities. Both inter-active and intra-active learning are important potential opportunities for learning new skills and competences that may help build capabilities of different kinds. To capture the learning processes and development of capabilities, we find that renewable electrification processes must be analysed from different angles – including projects, national-sectoral innovation systems, and their links to global value chains. This is necessary due to the globalised nature of renewable energy, where production of e.g., solar panels and wind turbines takes place in one part of the world (often in China), whereas deployment and use takes place in other countries, including Kenya and other low and lower-middle-income countries.

Theoretically, such learning processes may help build up different capabilities that are not only key to the renewable energy agenda, but also include potential for underpinning sustainable industrialisation in low and lower-middle-income countries. Physical technologies, skills, and knowledge/human resources as well as capabilities related to organisational change and ensuring linkages with other actors and within the value chain are required, and developing these will also have likely spill-over to other sectors as some of the capabilities may be re-used in other sectors and processes. The conceptual framework for analysing the potential of renewable energy processes to contribute to sustainable industrialisation (Figure 2.3) breaks down the capability-related co-benefits in the renewable electrification process into three key elements: learning, development of capabilities, and the resulting (expected) outcomes.

The second research question asks what conditions may turn opportunities for sustainable industrialisation from renewable electrification processes into reality? In our view, important opportunities for renewable electrification processes to foster sustainable industrialisation arise when local actors are given the possibility to learn from getting involved in different parts of the renewable energy value chains and when they are enabled to use lessons learned in new projects or contexts. Since most of the manufacturing in the renewable energy value chains takes place outside Africa, local actors are mainly engaged in the deployment and use of the technologies. They may learn new skills and capabilities e.g., when acting as local suppliers on renewable energy projects providing services such as site preparation, transportation of equipment (e.g., wind turbines), or electrical wiring and connecting of new projects to the national grid or to mini-grids. Capabilities acquired may subsequently be used in other sectors and for other purposes such as transportation and storage of agricultural products, agro-business, or other products linked to new ways of industrialising.

In order to fully understand what inter-active and intra-active learning takes place at different levels, stages, and in different locations, empirical work is required. A number of the chapters in this book therefore explore the processes related to acquiring and developing capabilities from the different angles presented in the nested view and focusing on what outcomes are generated from the processes (cf. the conceptual framework). For instance, Gregersen and Gregersen (2022; this volume) focus on learning spaces developed more or less deliberately in large-scale wind projects in Ethiopia and Kenya and what type of learning and capabilities are built in these two cases. Wandera (2022; this volume) focuses on opportunities and barriers for deployment of small wind turbine technology, while Nzila and Korir (this volume) provide an overview of the capabilities present in ongoing renewable energy projects in Kenya. Hanlin and Okemwa (2022; this volume) focus on development of (project management) capabilities in a range of critical projects in solar and wind energy in Kenya, while Karjalainen and Byrne (2022; this volume) present a detailed categorisation of firms involved in solar PV in Tanzania and Kenya based on the level of innovativeness and what capabilities the firms possess. Bhamidipati et al. (2022; this volume) review the learning, capabilities, and outcomes generated (or not) in connection with the increasing amount of Chinese investments in renewable energy projects in sub-Saharan Africa. Finally, Kingiri and Okemwa (2022; this volume) investigate how the energy policies in Kenya have changed over time and the extent to which local content issues have been on the agenda as a means of building capabilities in renewable energy that are also useful for a broader range of projects and sustainable industrial development.

In the final chapter of this book (Lema et al., 2022; this volume) we will return to the nested view and the conceptual framework and draw out conclusions and lessons learned from the field as presented in the various chapters of the book. For now, it is important to reiterate that the considerable investments in renewable energy projects in sub-Saharan Africa expected in the coming years provide an open window to maximise opportunities for interactive learning. This also includes opportunities for learning from the import of technology that is taking place through these investments. Such learning is essential as renewable energy systems irrespective of size and type (shape) must be installed/deployed on the ground under what is often quite challenging conditions.

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Notes

1 A recent report from the Global Commission on the Geopolitics of Energy Transformation also points to the far-reaching geopolitical implications of an energy transformation driven by the rapid growth of renewable energy (Irena, 2016).
2 A recent special issue of The European Journal of Development Research edited by Lema et al. (2018) and in particular the article on 'Innovation Trajectories in Developing Countries: Co-evolution of Global Value Chains and Innovation systems', however, brings in new evidence to the field and is related closely to the approach suggested here (Lema, Rabellotti, and Sampath, 2018a).
3 Presentation by Prof. Abdelkader Djeflat, MAGHTECH, during the 2nd AfricaLics International Conference, Kigali 2015.
4 The role of the state in development and the extent to which the state should be involved in R&D and in production of e.g., electricity is a huge debate in itself. See e.g., Mazzucato (2015) and Mazzucato (2018).
5 http://um.dk/en/foreign-policy/p4g---partnering-for-green-growth-and-the-global-goals-2030/ (accessed 2 September 2020).

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