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GLOSSARY

The entries in this glossary are primarily taken or modified from definitions provided by reports published by the Intergovernmental Panel on Climate Change (IPCC).

Climate technology	Climate technologies are those that help us reduce greenhouse gases and adapt to the adverse effects of climate change. (See definition of technology below).
Deployment	The act of bringing technology into effective application, involving a set of actors and activities to initiate, facilitate and/or support its implementation (IPCC 2022a).
Diffusion	The spread of a technology across different groups, users or markets over time (IPCC 2022a).
Enabling environment	The set of resources and conditions within which the technology and the target beneficiaries operate. The resources and conditions that are generated by structures and institutions that are beyond the immediate control of the beneficiaries should support and improve the quality and efficacy of the transfer and diffusion of technologies (Nygaard and Hansen 2015).
Feasibility	The potential for a mitigation or adaptation technology to be implemented. Factors influencing feasibility are context-dependent, temporally dynamic and may vary between different groups and actors. Feasibility depends on geophysical, environmental-ecological, technological, economic, sociocultural and institutional factors that enable or constrain the implementation of an option. The feasibility of options may change when different options are combined and increase when enabling conditions are strengthened (IPCC 2022b).
Governance	A comprehensive and inclusive concept of the full range of means for deciding, managing, implementing and monitoring policies and measures. Whereas government is defined strictly in terms of the nation State, the more inclusive concept of governance recognizes the contributions of various levels of government (global, international, regional, subnational and local) and the contributing roles of the private sector, of non-governmental actors and of civil society in addressing the many types of issues facing the global community (IPCC 2018).
Innovation	Both the processes of research and development and the commercialization of the technology, including its social acceptance and adoption (IPCC 2000). Furthermore, innovation is seen as the process of generation, acceptance and implementation of new ideas, processes, products or services (Thompson 1965) as well as an outcome – any thought, behaviour or thing that is new (Barnett 1953).
Innovation system	All important economic, social, political, organizational and other factors that influence the development, diffusion and use of innovations (IPCC 2000).
Institution	Rules, norms and conventions that guide, constrain or enable human behaviours and practices. Institutions can be formally established, for instance through laws and regulations, or informally established, for instance by traditions or customs. Institutions may spur, hinder, strengthen, weaken or distort the emergence, adoption and implementation of climate action and climate governance (IPCC 2022b).
Technology	Technology is “a piece of equipment, technique, practical knowledge or skills for performing a particular activity” (IPCC 2000). It is common practice to distinguish between three different components of technology (Müller 2003): • Hardware: the tangible component, such as equipment and products • Software: the processes associated with the production and use of the hardware • Orgware: the institutional framework, or organization, involved in the adoption and diffusion process of a technology These three components are all part of a specific technology, but the relative importance of each component may vary from one technology to another.
Technology transfer	The exchange of knowledge, hardware and associated software, money and goods among stakeholders, which leads to the spread of technology for adaptation or mitigation. The term encompasses both the diffusion of technologies and technological cooperation across and within countries (IPCC 2022a).
Transformative change	A system-wide change that requires the consideration of social and economic factors which, together with technology, can bring about rapid change at scale (IPCC 2018).
Transition	The process of changing from one state or condition to another in a given period of time. Transition can occur in individuals, firms, cities, regions and nations, and can be based on incremental or transformative change (IPCC 2022a; IPCC 2022b).

CONTENTS

FOREWORD

The need for urgent transformational change to achieve the goals of the Paris agreement has been highlighted by recent UNFCCC, IPCC and WRI reports. Upscaling the implementation of effective development and transfer of climate technologies in response to the climate is more crucial than ever. Technologies are key to sustainable development and the interlinked issues of the triple planetary crisis that humanity currently faces: climate change, pollution and biodiversity loss.

It is essential to understand the processes leading to the successful development and transfer of technology, the gaps and enablers, and the context-dependent conditions that need to be in place. However, the available information is fragmented, often unsystematic and outdated, with a focus that is either too aggregated or too localized.

This 'Climate Technology Progress Report' is produced and published as a collaboration between the UNEP Copenhagen Climate Centre and the UNFCCC Technology Executive Committee (TEC). The report will be regularly updated with regional-level analyses of feasibility, enabling environments and technology progress, and supplemented with detailed case studies to inform national and international action. The aim is to enhance our understanding of the progress being made on technology development and transfer, progress enablement, and the need for gap filling, to assist decision makers in their choices for strategic and catalytic actions and investments, and for Parties to use the report's findings in discussions of technology development and transfer under the UN Climate Convention.

This year's report focuses on establishing an approach for future tracking of progress on technology development and transfer, and subsequently applying this approach using data from Africa. The report shows that the systematic methodology of feasibility assessment provides a reproducible and transparent approach for examining technologies that are feasible to adopt, also identifying knowledge gaps. The report highlights the effectiveness of financial investment on agricultural technologies in Africa; the need to consider subregional variations in the feasibility of energy technologies; and the need to nurture the development of institutional, social and policy capabilities through long-term programmatic activities.

The report also highlights the importance of financial interventions not only to compensate viability gaps for individual transactions, but to help resolve market failure and contribute to market creation for climate technologies; and the important intersection between climate action and development needs where major developmental issues, including access, equitable development, and distributional aspects, need to be addressed alongside the implementation of climate technologies.

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EXECUTIVE SUMMARY

1. INTRODUCTION

Context

The effective utilization of technology is key to meeting national and international climate adaptation and mitigation objectives and building resilient and sustainable economies. Many technologies related to a broad range of economic sectors offer substantial opportunities and solutions to cut emissions and adapt to climate change. At the same time, further development and transfer of new or currently immature technologies are also necessary to fully achieve net-zero goals. Therefore, effective and accelerated technology development and transfer are imperative. The main focus of this report is to assess what can be done to move ahead in amplifying climate action.

Within the United Nations Framework Convention on Climate Change (UNFCCC), the role and importance of technologies have received clear and consistent support from parties to the UNFCCC for over 20 years. The Paris Agreement sets out a global framework to avoid climate change by limiting global warming to well below 2°C and by pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' abilities to deal with the impacts of climate change and support them in their efforts.

The Technology Framework – established under Article 10 of the Paris Agreement and elaborated as part of the Paris Agreement work programme agreed to at the twenty-fourth Conference of the Parties to the UNFCCC (COP 24) in 2018 – offers a distinct opportunity to further shape and strengthen the work under the UNFCCC and the agreement to foster and accelerate action at different stages of the technology cycle.[1] During COP26, in 2021, countries came together and emphasized the importance of strengthening cooperative action on technology development and transfer for the implementation of mitigation and adaptation action in the Glasgow Climate Pact (UNFCCC 2021a). This year, in 2022, the Periodic Assessment of the Technology Framework and the Global Stocktake of the implementation of the Paris Agreement are being undertaken by the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement (CMA).

The findings of this report are expected to be useful to Parties to the UNFCCC when discussing technology development and transfer. The report is primarily targeted at national and international planners, decision makers as well as other stakeholders within the UNFCCC constituency. It is also envisaged to be of use to multilateral and bilateral development agencies when planning programmatic interventions.

Focus and structure

Having a limited understanding of the feasibility of and enabling conditions for technology development and transfer highly impacts the potential for the different climate technologies to be implemented. Therefore, this report will provide systematic and annual assessments of the current state of existing feasibility and required enabling conditions for technology development and transfer at sectoral and regional levels. The report asks the following questions, all centred around feasibility and enabling conditions for reaching a higher degree of technology development and transfer:

1. What progress is made?
2. What has enabled it?
3. Where are the gaps?
4. Building on this understanding and ambition, how do we better enhance climate technology development and transfer?

Developing the 2022 scoping edition of this report has been an iterative process, in which the thinking and focus have been shaped along the way. The report focuses on the establishment of an approach to measure and track progress on technology development and transfer and to provide snapshots of what shapes that progress.

The report has been guided by an experienced Steering Committee and prepared by an international team of experienced scientists, who have developed the approach and applied it on data from Africa. From 2023, the report aims to provide annual insights on climate technology progress, focusing on both industrialized and developing countries, providing both a local and global perspective.

1 Including research and development, demonstration, deployment, diffusion and transfer of technology.

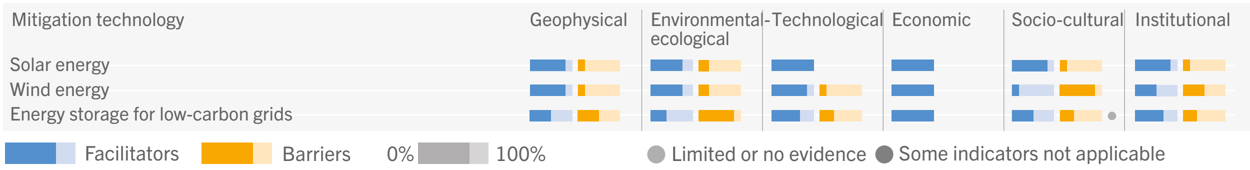
2. FEASIBILITY ASSESSMENT

The FA shows how the approach can identify knowledge gaps where more research is needed to understand the implications of certain technologies. The results shown in this scoping report reflect the synthesis of the information in the peer review literature as defined by the IPCC mandate. Applying expert consultations with stakeholders, rights holders and users of the technology or technologies, and using grey literature in the FAs would be an important innovation in order to implement these analyses at a regional and country level, which have the benefit of more fully capturing the local context.

For mitigation, a rapid increase in the transition to using renewable energy technologies forms a cornerstone of climate mitigation policy. An overview of the feasibility assessment (FA) of energy technologies are shown in figure 2. At the global level, many factors facilitate the implementation of solar and wind energy. Specifically, these technologies are geophysically, technologically and economically feasible. Overall, solar energy is a feasible option across almost all dimensions, but care should be taken to address some barriers, specifically related to land use, distributional effects, recycling and in some cases political support. Solar energy faces few sociocultural barriers as it carries positive impacts on human health and well-being. However, high upfront costs may inhibit the adoption of solar photovoltaics (PV) for low-income individuals and communities as well as in developing countries. The feasibility assessment also shows that despite earlier concerns, solar energy has overcome initial institutional, legal and administrative challenges. However, political acceptance remains low in some countries because of opposition from vested interests such as electricity companies and competition with land use. By displacing fossil fuels, solar energy also offers environmental benefits, but it often uses substantial land, which means that without strategies and policies to address the multiple uses for land, solar energy may threaten biodiversity and compete with agriculture and housing in densely populated areas. At the end of their life cycle, solar PV panels can contribute to toxic material waste, including its batteries in case of standalone distributed generation systems. For other components, waste can be avoided by recycling the material, which mostly consists of glass and is easily repurposed.

Figure A. Feasibility assessment of energy adaptation and mitigation technologies

Panel A - Renewable energy mitigation technologies



Source: Based on Figure TS.31 from IPCC (IPCC 2022a)

3. GOVERNANCE: INSTITUTIONS, POLICIES AND SOCIAL DIMENSIONS

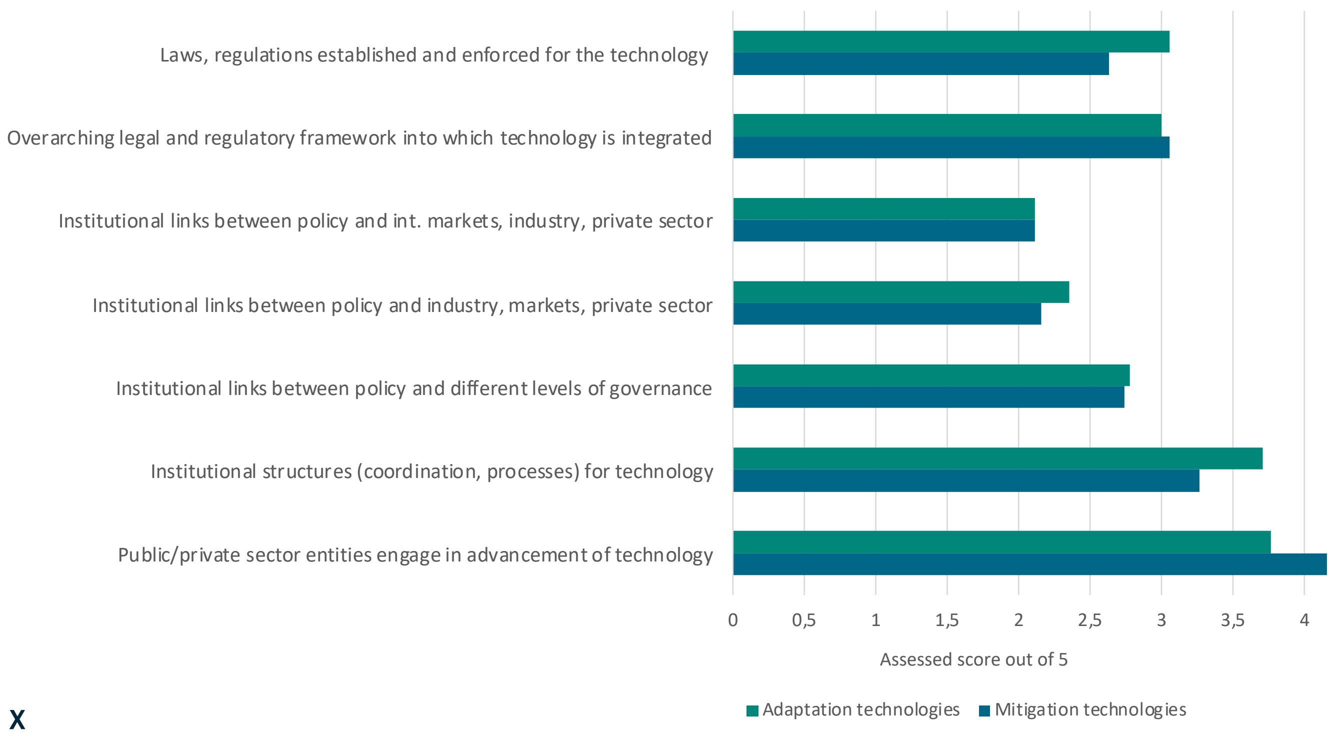
Enabling environments require more than developing modalities for technology development and transfer. It refers to wider and context-specific dimensions that converge to form a part of innovation processes at the country and international levels, affecting their development.

Climate technologies are essential to advance low-carbon, climate-resilient development pathways, but only insofar as resources and capabilities are available to the stakeholders who are engaged in making decisions and implementing climate technology programmes and projects. Much of the technological capabilities of countries hinge on public and private actors engaging in coordination and on technology stakeholders having the capacities needed to catalyse finance for climate technology development and transfer into their national socioeconomic contexts.

Results from a survey conducted with African stakeholders shows progress as well as areas where significant improvements are needed in several dimensions of enabling environments for technology development and transfer. African stakeholders perceived overall moderate progress in the establishment of an enabling environment for mitigation and adaptation technologies. However, there is relatively uneven distribution of progress across enabling dimensions assessed, with a particularly limited progress on finance for climate technology development and transfer. Figure B presents the progress on enabling environments assed for institutional, legal and policy dimensions. A low score represents little or no progress and a high score represents high progress.

Further work on integrating climate technology and governance frameworks at national level is essential to the delivery of successful climate technology projects in developing countries in the short, medium and long term.

Figure B. Average scores assessed for indicators in the institutional and legal dimensions of the enabling environment for adaptation and mitigation technologies



4. FINANCE

Finance holds a key role in relation to the structural constraints that inhibit technology development and transfer in general, notably for resourcing the enabling environment, and with regard to the access to and cost of finance. These same factors are often aggravated in the context of technologies, from technologies procured and public infrastructure investment to those used by smallholder producers or private consumers. Specific factors in this regard include the need to build capacity – i.e. to expand the enabling environment – for new technologies in developing countries as well as the high capital intensity of many climate technologies, which magnify constraints that result from the limited access to and high cost of finance.

The tighter the constraints of public finances are in developing countries, the more important the role of development finance becomes. In particular, in countries with low-income levels, donor financing can constitute a significant share of total support for resourcing the enabling environment for technology development and transfer.

Large-scale investment required for achieving sustainable development based on climate-resilient, net-zero pathways will require the mobilization of finance from private markets, while the direct financing of investments projects that deploy climate technologies will remain an important dimension of international support. To contribute most effectively towards this mobilization in light of its basic limitations of scale, development finance must be deployed in a catalytic fashion. A financial sector that provides access to finance and the availability of financial services plays a key role in addressing the constraints identified by developing countries in terms of cost and affordability of technology, from large-scale infrastructure to individual consumers and microentrepreneurs.

Overall, the availability of financial services for investment is a basic factor for the viability of technology development and transfer. This makes financial services an essential factor for the overall enabling environment for climate technology transfer and investment. Both general progress with financial development as well as targeted interventions focusing on "green" finance can help increase financing for climate technologies and associated investments. Finally, financial interventions are most effective if they are deployed not only to compensate viability gaps for individual transactions but also to help resolve market failure and contribute, beyond direct mobilization, to market creation for climate technology development and transfer.

5. PROGRESS ON CLIMATE TECHNOLOGY DEVELOPMENT AND TRANSFER IN AFRICA

Climate technology development and transfer is progressing at a varied pace across sectors, countries and regions. Progress is driven by national policies, institutions and actors in concert with international efforts. Certain sector-specific innovation policies are well developed and streamlined across most African countries, notably in the energy sector, such as feed-in-tariffs, VAT exemptions and product standards. Particularly in the solar sector, we see a high degree of implementation of standards and certification both in regard to products as well as technical training and skills programmes. Some countries stand out when it comes to implementing clean energy policies, scale of markets and levels of diffusion. These include Kenya, South Africa, Ghana, Nigeria, Egypt and Morocco, which are also the countries with the highest concentrations of innovation hubs and start-up ecosystems around climate technology innovations.

The availability of data impacts our understanding of technology development and transfer progress. Data is more available for some sectors, technologies and regions than for others. While data on solar and wind development in the relatively developed African countries (e.g. Kenya, South Africa, Nigeria) is readily available, significantly limited data exists on mitigation technologies and progress in other countries such as those in the central African region (including Central African Republic, Congo, Cameroon, Gabon and Chad).

When looking at interventions, projects and programmes to diffuse climate technology, progress is often reflected in the form of pilot projects, demonstrations or initial deployment rather than in the form of scaled up interventions. Some scale-up programmes are being driven by international organizations in selected countries. **However, given the varied developmental contexts among countries in Africa, replicability and scalability have yet to become a reality for several technologies and sectors**. These efforts must also be made alongside strengthening absorptive and innovative capacities and maximizing socioeconomic benefits at the country level.

The linkages between science and innovation policy and the development and transfer of climate technologies are somewhat vague and not clearly understood, apart from the specific cases where science technology hubs are densely concentrated and show strong progress in technology diffusion (e.g. Kenya, South Africa, Nigeria and Egypt). The innovation ecosystem is more evolved in some countries in Africa. **The stages of technology development and innovation also entail, in many cases, deeper levels of industrialization strongly linked to economic development**.

1. Introduction

Lead author:
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1.1 CONTEXT

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) lays out clear evidence that the time for ambitious action is now and that such action must be expected to continue over the coming decades. Limiting warming to 1.5°C requires global greenhouse gas emissions to peak before 2025 at the latest and reach net-zero carbon dioxide emissions in the early 2050s. Emissions must drop by almost 10 per cent per year globally, and resilience to climate change impacts needs to be built (IPCC 2022a). This urgency is further underlined in the Emissions Gap Report 2022, which calls for a rapid transformation of societies to achieve the temperature goal of the Paris Agreement (UNEP 2022). At the twenty-sixth Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 26) in 2021, the importance of strengthening cooperative action on technology development and transfer for the implementation of mitigation and adaptation action was emphasized in the Glasgow Climate Pact (United Nations Framework Convention on Climate Change [UNFCCC] 2021a).

The effective utilization of technology is key to meeting national and international climate adaptation and mitigation objectives and building resilient and sustainable economies. Many technologies related to a broad range of economic sectors offer substantial opportunities to cut emissions and adapt to climate change. At the same time, further development and the transfer of new or currently immature technologies are also necessary to fully achieve net-zero goals. Therefore, effective and accelerated technology development and transfer are key, which is why this report focuses on what can be done to move ahead with creating action in this regard.

Within the UNFCCC, the role and importance of technologies have received clear and consistent support from parties to the Convention for over 20 years. Landmark decisions include the introduction of the framework for meaningful and effective actions to enhance the implementation of article 4, paragraph 5, at Marrakesh (2001), later enhanced in Bali (2007); the establishment of the Poznan strategic programme to scale up the level of investment for technology transfer under the Global Environment Facility at COP 13; the establishment of the UNFCCC Technology Mechanism, the Technology Executive Committee (TEC) and the Climate Technology Centre and Network at Cancun (2010); the enhanced action on technology development and transfer to support action on mitigation and adaptation at Doha (2012) and finally the Paris Agreement (2015).

The Paris Agreement sets out a global framework to avoid climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts. Article 10 of the Agreement1 sets the scene for cooperation on technology through "promoting and facilitating enhanced action on technology development and transfer in order to support the implementation of the Paris Agreement in pursuit of the long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions".

The Technology Framework – established under Article 10 of the Paris Agreement and elaborated as part of the Paris Agreement work programme agreed to at COP 24 in 2018 – offers a distinct opportunity to further shape and strengthen the work carried out under the UNFCCC and the Paris Agreement to foster and accelerate action at different stages of the technology cycle.[2] This year, in 2022, the Periodic Assessment of the Technology Framework and the Global Stocktake of the implementation of the Paris Agreement are being undertaken by the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement (CMA). The findings of this report are expected to be useful to Parties when discussing technology development and transfer.

Technology development and transfer is complex, non-linear and depends on many contextual factors. Several challenges often prevail, hindering the development and transfer of technology and leading to lower development and transfer of technologies via traditional market mechanisms. This includes the country-specific circumstances that encompass existing market and technological conditions, institutions, resources and practices, which can be subject to changes in response to government actions.

There exist several well-established reports providing regular overviews and analyses of climate technologies and trends. These include reports focused on energy technology demand trends and future needs such as World Energy Outlook and Energy Technology Perspectives produced by the International Energy Agency, and on development in available energy technologies and related financial aspects such as the Energy Transition Outlook produced by Det Norske Veritas (DNV) and State of Climate Technologies by PricewaterhouseCoopers (PwC).

1 Decision 1/CP.21, Annex, Article 10

2 Including research and development, demonstration, deployment, diffusion and the transfer of technology.

Furthermore, the State of Climate Action report, led by the World Resources Institute, assesses the means of achieving decarbonization pathways towards defined targets. These reports provide comprehensive information on existing and new climate technologies, and in particular investment opportunities and pathways for mitigation initiatives. In addition, there are also the United Nations Environment Programme's (UNEP) annual Emissions Gap and Adaptation Gap reports, which each year lay the groundwork for our current climatic situation and where we need to be in terms of mitigation and adaptation action, complementing the fundamental assessments by the IPCC. This report, the Climate Technology Progress Report (CTPR), contributes to the existing body of literature by providing regular analysis of progress on enabling environments that can inform action on technology development and transfer at the national and international levels.

1.2 FOCUS AND STRUCTURE

The focus in this report is on climate technologies and how to enhance their development and transfer.

In this report, the understanding of what a technology is follows the definition laid out by the IPCC (2000), where a technology is "a piece of equipment, technique, practical knowledge or skills for performing a particular activity". For simplicity, technology development and transfer is understood as a concept that comprises development, demonstration, deployment, diffusion, transfer and uptake.

To enhance technology development and transfer, it is essential to understand the processes leading to successful development and transfer in general, and thereby to understand the reasons or barriers as to why certain targets in this regard are not fully realized. Furthermore, it is essential to understand the required enabling environment for technology development and transfer. An enabling environment for enhanced technology development and transfer consists of resources and conditions that are generated by different structures and institutions. In this report, there is also a focus on feasibility. Feasibility presents the potential for a mitigation or adaptation technology to be implemented. The feasibility for technology development and transfer, alongside its enabling conditions, are interlinked, whereas feasibility increases when enabling conditions are strengthened. Further details can be found in chapter 2 and in the glossary.

There remain deficiencies in existing knowledge on the technologies needed, as needs evolve and change over time, and on the conditions that are required in different contexts to foster enabling environments for their development and transfer. The available information is fragmented, spread across many sources, not systematic and often outdated. Furthermore, the existing available information is generally presented with a focus either on the very local level or on an aggregated global overview.

Having a limited understanding of the feasibility of and the enabling conditions for technology development and transfer highly impacts the potential for the different climate technologies to be implemented. Therefore, this report fills a gap wherein it provides systematic and annual assessments of the current state of existing feasibility and the required enabling conditions for technology development and transfer at sectoral and regional levels.

This report asks the following questions, all of which centre around the feasibility and enabling conditions for reaching a higher degree of technology development and transfer:

1. What progress is made?
2. What has enabled it?
3. Where are the gaps?
4. Building on this understanding, how do we better enhance climate technology development and transfer?

Developing this scoping edition of the report has been an iterative process, in which the thinking and focus has been shaped along the way. This report focuses on the establishment of an approach to measure and track progress on technology development and transfer and to provide snapshots, due to its scope, of what shapes that progress. Through an application of the data approach from Africa, this report reflects on what shapes the feasibility and enabling conditions for technology development and transfer in the specific context. From 2023, the report aims to provide annual insights on the progress, focusing on both industrialized and developing countries while providing both a local and global perspective.

This report is primarily targeted at national and international planners and decision makers as well as other stakeholders within the UNFCCC constituency. It is also envisaged to be of use to multi- and bilateral development agencies when planning programmatic interventions.

The report is structured in three parts:

Part A evaluates a range of climate mitigation and adaptation technologies using the feasibility assessment (FA) approach. The FA prioritizes the identification of barriers and enablers of mitigation and adaptation technologies. Importantly, this approach reveals which barriers – if removed – would make this technology more feasible to implement. In this way, the FA addresses one of the key questions for decision makers, specifically: what more do we need to do to make this happen?

Part B goes more in depth with different dimensions of the enabling environment that affect the feasibility of adaptation and mitigation technologies. The 2022 report focuses on two of these dimensions, namely governance and finance, both of which are identified by countries as being among the main challenges for accelerated action on technology development and transfer.

Part C provides an initial exploration of climate technology transitions in Africa, offering contextual detail, highlighting the key roles of different actors and providing an analysis of progress and climate technology mega-trends in African countries across three sectors – energy, water and agriculture.

Chapter 2 provides more detail on the methodology of this report while chapters 3, 4, 5 and 6 each seeks to answer the aforementioned questions through different perspectives. Chapter 3 presents the FA, while chapters 4 and 5 present the analyses of governance and finance as enabling conditions. Finally, chapter 6 investigates in more detail the technology transitions in Africa.

Katse dam wall in Lesotho, Southern Africa
Shutterstock

2.

Approach

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2.1 INTRODUCTION

This chapter outlines the approach undertaken in this scoping report and indicates further work ahead of the annual Climate Technology Progress Report (CTPR) series commencing in 2023. As the CTPR is the first report of its kind, its approach is deliberately an interim product that aims to test and elicit feedback on the methodology. The scoping edition of this report tests the approach on data for climate technologies for agriculture, energy and water in African countries.

This scoping report uses three approaches to assess the development and transfer of climate technologies: a multidimensional feasibility assessment (FA) utilizing peer-reviewed and other literature, a survey of enabling environments for specific technologies by government officials and a detailed case study analysis on select climate technologies. In sections two, three and four, we provide details on these methods and how they are applied in this scoping report. The final two sections of the chapter outline some issues of overlap across the methods, discuss potential work before the annual report series commencing in 2023 and lay out additional elements that the report series aims to deliver.

2.2 FEASIBILITY OF A TECHNOLOGY: BARRIERS AND FACILITATORS

2.1.1 Overview and rationale

Part A of this scoping report provides an assessment of the feasibility of agriculture, energy and water technologies at the regional level in Africa and at a global level. The list of sectors will be expanded to cover all possible sectors in subsequent reports. The list of technologies included in this scoping report align with the adaptation and mitigation options assessed for the Sixth Assessment Report (AR6) (Intergovernmental Panel on Climate Change [IPCC] 2022c; IPCC 2022b). A FA method is used in this scoping report to provide a high-level overview of the feasibility of various climate technologies, how those technologies fit within broader systems transitions and synergies and trade-offs among technologies.

Feasibility in this scoping report is defined as the potential for an adaptation or mitigation technology to be implemented (see glossary). The FA in this report builds on the evaluative approach undertaken within the IPCC's AR6 (IPCC 2022a; IPCC 2022b). In assessing feasibility, the focus is on identifying the barriers and facilitators[3] to the implementation of any given technology across six dimensions: economic, environmental-ecological, geophysical, institutional, technological and sociocultural (Singh et al. 2020). Within each of these dimensions, a set of indicators is selected as the basis for the assessment. The assessment is conducted via a comprehensive review of academic and policy literature for each technology and against all indicators.

In the IPCC Reports, the FA provides policy makers with information about which technologies are the most feasible at global and regional levels. The assessment also identifies which dimensions of barriers to and facilitators of feasibility exist along with providing information on said barriers and where additional actions may be needed to remove the barriers. The FA approach also provides a conceptual framework that can help guide national-level thinking on climate change technologies for mitigation and adaptation. The approach outlined in this scoping report includes locating specific technologies within broader system transitions and identifies synergies and trade-offs across different technologies. For example, adaptation technologies such as forest-based adaptation and resilient power infrastructure also help to reduce emissions. As feasibility is context-specific, the assessment does not replace the need for detailed country-level assessments of specific technologies. Such country-level assessments would also benefit from a consideration of the desirability and viability of specific technologies within a country.

2.2.2 Feasibility assessment

The multidimensional FA applied in this scoping report aims to assess the feasibility of adaptation and mitigation technologies across six dimensions. Each dimension comprises four or five indicators which, combined, provide the basis for a score of low, medium and high for each dimension. The set of indicators can be adjusted depending on the priorities, needs and scales of regions and countries. Chapter 3 demonstrates the FA at the global level and at the regional level in Africa, showing the changes in indicators that reflect, not only in terms of the context, but also the availability of information. The results of the FA shown in chapter 3 of this scoping report derive from the IPCC's AR6. Alongside the feasibility of the technologies, the FA also helps identify synergies and trade-offs between mitigation and adaptation and their nexus with the Sustainable Development Goals (SDGs).

3 The assessment of mitigation options includes barriers and facilitators, with the assessment of adaptation options only focused on barriers.

2.3 ENABLING ENVIRONMENT: ENHANCING THE DEVELOPMENT AND TRANSFER OF A TECHNOLOGY

2.3.1. Overview and rationale

Part B of this scoping report complements the FA by analysing additional factors that influence the extent to which feasible climate technologies are developed and taken up at the national level. A survey methodology was selected for this scoping report to gather information from national-level decision makers on the actions taken to enhance the enabling environment for specific technologies (details of the method outlined in the section below). The existing analysis of enabling environments consists primarily of detailed, single-country case studies. A survey, by comparison, provides a means to collect data using a common set of criteria across many countries and the possibility of measuring progress against the indicators assessed over time.

The analysis of the survey data focuses on the aggregate progress in and across indicators and dimensions of the enabling environment, rather than on the progress of individual countries. Reflecting the fact that any analysis of enabling environments is technology- and national context-specific, the scoping report does not prescribe action, but rather identifies elements of a framework for developing an effective enabling environment for the technologies that countries choose to prioritize. It does so by identifying critical indicators and connections between these indicators and across the dimensions of the enabling environment. The framework could also be used to inform decisions on priorities based on the status of key indicators of the enabling environment for specific sectors or technologies.

A central part of the survey analysis is identifying connections between and across indicators and dimensions of enabling environments as well as drawing attention to how different indicators of the enabling environments are developing within and across countries for specific technologies. For example, aggregate technologies may be included in a national climate change policy, such as within a nationally determined contribution, but not linked to other relevant policies for that technology (economic/financial, education and training, innovation or sustainable development policies), or they may be connected across the different levels of governance responsible for implementing the policy or lack funding under the national budget. Another example might be that technologies are receiving funding from the national budget but may not be effectively linked to other potentially valuable funding such as through international sources of private or public funding or institutional links with national or international industry, markets or the private sector.

2.3.2. Survey method

The scoping report utilizes results from a survey of government officials with portfolio responsibility for climate technologies in 52 African countries. The officials surveyed were identified by two means. First, officials in those ministries responsible for the United Nations Framework Convention on Climate Change (UNFCCC) technology needs assessment. Second, where countries had not completed a technology needs assessment process, officials nominated by governments to undertake the role as the national designated entity to the Technology Mechanism of the UNFCCC were surveyed. Twenty-two countries responded to the survey with responses related to one adaptation and one mitigation technology.[4]

Survey respondents were asked to assess the progress of specific climate change technologies (one adaptation and one mitigation technology) in the enabling environment in their country. The technologies assessed were selected by the respondents; no determination was made as to whether they were representative of the sectors, nor of adaptation or mitigation technologies more generally.[5] The respondents evaluated progress by responding to multiple-choice questions with each respondent selecting from five specific options the response that most closely resembles the situation in their country for their designated technology (see box 1 for an example of the question format).

A five-point scale was chosen to enable countries to assess progress along a range of possibilities. The multi-point scale also provides a framework within which incremental progress over time within countries can be captured and which enables cross-national comparison.

4 The countries that responded to the survey are as follows: Benin, Burundi, Chad, Comoros, Djibouti, Egypt, Eswatini, Guinea, Guinea Bissau, Kenya, Lesotho, Namibia, Democratic Republic of Sao Tome and Principe, Senegal, Seychelles, Somalia, United Republic of Tanzania, Tunisia and Uganda.

5 The adaptation technologies assessed were climate resilient crops, drip irrigation, mangrove restoration and regeneration, rainwater harvesting, watershed management, water reservoirs and water use meters. The mitigation technologies assessed were agroforestry, biomass electricity generation, conservation agriculture, energy-efficient infrastructure, geothermal energy generation, rooftop solar PV, solar pumping and solar water heaters.

Box 1. Example of the question type and structure included in the survey completed by countries

Check the box next to the most relevant description

- ■ 5. Specific economic and/or financial policies established and effectively implemented for the climate technology e.g. tax exemptions, subsidized credit or feed-in tariffs for a climate technology.
- ■ 4. Specific economic and/or financial policies established for the climate technology where the establishment is partial and/or implementation yet to begin or has only recently begun.
- ■ 3. Existing plans to establish such mechanisms for the climate technology where the policies have not yet been established.
- ■ 2. Plans to establish such mechanisms where the work is still at the initial stages of planning only.
- ■ 1. Absence of any plans or consideration of planning to establish economic and/or financial policies to support the climate technology.

The survey indicators used for this scoping report cover the financial, institutional, policy and behaviours, lifestyles and norms dimensions of the enabling environment (see annex A for the list of indicators). The indicators selected for this scoping report reflect those aspects of the enabling environment most frequently referenced by countries as part of the technology needs assessment process. In this process, countries identify and prioritize climate technologies they intend to develop, the strategies by which the government plans to advance that technology and the barriers and enabling conditions the country plans to address to advance the technology. The indicators also reflect a review of relevant literature on enabling environments, focusing on the IPCC reports. The review encompassed literature on the enabling environment for adaptation actions in Africa (Trisos et al. 2022), for the 1.5°C mitigation pathways (de Coninck et al. 2018) and for climate mitigation technologies (Blanco et al. 2022; Nygaard and Hansen 2015; Trærup, Greerson and Knudson 2018). Climate technology is a part of broader efforts to adapt to and mitigate climate change. For this reason, and because the literature on the enabling environment specifically for climate technologies is less well studied, the literature review encompassed the broader literature on enabling environments for climate change actions.

While this scoping report focuses on testing methods, the results presented not only demonstrate the types of insight possible using the method adopted, but also offer an interesting snapshot of the thinking of relevant officials in 22 African countries.

2.3.3. A collation of relevant indicators of progress from existing sources

The survey analysis was complemented by a set of additional national, regional and global indicators from various academic, intergovernmental and other sources. For example, in assessing climate finance, cross-border payments and receipts for intellectual property provide a proxy for cross-border finance for technology use, as does trade data for sectors critical to climate technologies. These indicators will fulfil two functions. First, they will fill in aspects of the enabling environment not assessable via the survey of government officials. Second, they will provide a means to help triangulate results of the survey. In the scoping report only the finance chapter uses these indicators. A complete set of indicators will be developed for the various dimensions of the enabling environment for inclusion in the annual report series.

2.4 CASE STUDIES

Part C of this scoping report comprises of a case study analysis. The cases selected were based on an analysis of macrotrends in Africa and covers agriculture, energy and water. The case study analysis reflects upon these macrotrends and draws upon the FA (Part A) and analysis of enabling environments (Part B) to better understand the factors influencing progress among the select climate technologies.

Table 1 – Overview of methods and their application as relevant to national, regional, and global policy- and decisionmaking audience

Level	Method	Scope	Application	Part of Report
National	Case study	National level action on an aspect(s) of the enabling environment	Knowledge of lessons learned on aspects of enabling environments for specific technologies	C
	Survey	National enabling environments in focus region	Knowledge on connections between aspects of the enabling environment based on countries' experiences	B
	Feasibility Assessment	Technologies at regional and global level	Data on technologies within broader systems transitions and synergies and trade offs between technologies	A
Regional	Survey	National enabling environments in focus regions	Data on progress within and across regions and over time on aspects of the enabling environment for specific technologies	B
	Feasibility Assessment	Technologies at regional and global level	Data on progress within and across regions and over time aspects of feasibility for technologies and systems transitions	A
Global	Survey	National enabling environments across various regions	Data on progress across regions and over time on aspects of the enabling environment for specific technologies	B
	Feasibility Assessment	Technologies at regional and global level	Data showing global progress over time, and across and within regions over time, on aspects of feasibility for technologies and systems transitions	A

2.5 OVERARCHING METHODOLOGY AND ADDITIONAL CONSIDERATIONS

The approaches applied in the CTPR offer different insight to policymakers at the national, regional and global levels.

While the FA and survey of enabling environments have different objectives, there is some minor conceptual overlap. For example, the mitigation component of the FA considers enablers as a way of counteracting barriers whereas the assessment of adaptation technologies only focuses on barriers. In the enabling environment analysis in this scoping report, enablers provide a means to overcome barriers and enhance the likelihood of a technology being developed and taken up. These differences are reflected in the type of assessment conducted. The FA identifies whether enablers are present and the enabling environment analysis uses a five-point scale to assess the degree to which an effective enabling environment has been established, based on the assessments of survey participants. There is also some overlap in scope, as reflected in the dimensions they examine (see Table 2). However, the specific indicators within the respective sets of dimensions differ, and show that the FA and enabling environment analysis provide distinct information. These analyses also provide different levels of detail on these indicators.. The analysis of enabling environments in this scoping report focused on various dimensions described in the literature (Haselip et al. 2015; Nygaard and Hansen 2015; Trærup, Greerson and Knudson 2018).

Table 2 – Dimensions of feasibility assessment and analysis of enabling environments. Dimensions with asterisk are not addressed in the Scoping Report

Feasibility Assessment	Enabling environment
Economic	Behaviours, lifestyles, norms*
Environmental & ecological	Finance*
Geophysical	Governance
Institutional & Political	Institutional capacity*
Socio-cultural	Markets and private sector
Technological innovation	Policy*
	Technology and innovation

Note: The dimensions with an asterisk are assessed in this scoping report

2.6 THE FIRST ANNUAL CLIMATE TECHNOLOGY REPORT

The first annual CTPR in 2023 will build off the foundation established in this scoping report. Further developments in the methods employed are being considered. For example, the FA utilizes peer-reviewed and other literature, but expert elicitation could also be used as well as extending the review of materials to other sources. These developments could be important to better understand specific contexts at the national level. Consideration could also be given to identify additional ways to inform policymakers, which could include greater alignment between the approaches for adaptation and mitigation, including the consideration of enablers. Further developments to the analysis of enabling environments could also be considered. For example, additional verification of the survey results through qualitative interviews with representative survey participants and interactive workshops with survey participants where the results of the survey could be discussed. The dimensions of the enabling environment considered and the specific indicators employed in this scoping report could also be further assessed.

The annual nature of the CTPR series will offer additional insight beyond that found within the scoping report. The annual feasibility assessments should provide valuable insight into the UNFCCC process on how feasibility changes globally and across different regions over time. In identifying gaps in the literature on feasibility, the assessments may provide a valuable resource for informing the research agenda on dimensions of feasibility for climate technologies. The survey of government officials will also be repeated annually. These annual assessments will provide insight into how indicators and dimensions of the enabling environment have progressed within regions and how specific regions have progressed relative to other regions across time. In doing so, the CTPR can inform national policymaking as this data can provide valuable benchmarks to guide policymakers' thinking on the possibilities and constraints in their region. This data can also inform global decision-making on climate change (finance, policy and programmes), specific global processes like the global stocktake under the UNFCCC and highlight areas where countries would benefit from additional targeted investment.

Tana River watershed, Kenya

Part A

3.

Feasibility of Climate Technology Options across System Transitions

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3.1 INTRODUCTION

This chapter sets out a multidimensional feasibility assessment (FA) of a range of climate technologies. The FA provides a screening tool for decisionmakers by assessing the current state of feasibility of climate technologies along a set of key dimensions, thereby aiding in prioritization of technology options and indicating where strategic investment should be made to increase feasibility for technology development and transfer centrally. The FA reveals which barriers – if removed, managed or minimized – would make the relevant technology more feasible to implement. It also provides information about overarching barriers that hinder system transitions, such as a lack of political will towards the implementation of enabling policies and the presence of market distortions such as fossil fuel subsidies. Finally, the FA highlights areas where there are knowledge gaps, thus signaling areas for research priorities. It should be noted that feasibility is context-specific and that the assessments outlined in this chapter offer guidance to feasibility at the global and regional levels, rather than an indication of the feasibility of the technologies assessed within individual countries.

The FA presented in this chapter draws on the multidimensional analysis in the IPCC's Special Report on Global Warming of 1.5°C (SR1.5) and the IPCC's Working Group 2 and Working Group 3 contributions to the Sixth Assessment Report (AR6). Specific attention is given to applications in Africa, which also serves to highlight how FAs can be applied in different regional contexts and, specifically, that the FA is flexible in that indicators that are used to operationalize the dimensions of feasibility can be changed depending on context and location. This chapter has five sections. Section 2 describes the methodology used, section 3 provides examples of the global assessment, section 4 provides details of the African FA, and section 5 provides conclusions and recommendations for the use of the FA as part of an annual series of climate technology reports.

3.2 THE FEASIBILITY ASSESSMENT APPROACH

This now well established methodology originating in the SR1.5 provides the basis on which the feasibility of technology options can be assessed (see annex B for full details on how the FA approach was applied for this chapter). Feasibility of options is defined as "the degree to which the response options are considered possible" (IPCC 2018). Feasibility is operationalized by first identifying the critical dimensions of feasibility, and second evaluating the performance of the technologies on indicators that capture key elements of these dimensions. Figure 1 illustrates the 8-step process the multidimensional FA for different adaptation and mitigation technology options follows (Singh et al. 2020). This chapter focuses on the assessment of select adaptation and mitigation technologies which were chosen due to the robust evidence for their assessment.

Feasibility for the global-level analysis conducted by the IPCC was defined along six dimensions: economic, technological, environmental, geophysical, sociocultural, and institutional. Indicators are then developed for dimensions. In Table 3, the indicators chosen for the technological feasibility dimensions for adaptation and mitigation are shown. The differences between these indicators highlights how different characteristics matter for feasibility for these different applications.

In sections 3 and 4 the differences in indicators between the global and African region assessments, which are mainly due to contextual issues or issues regarding the availability of information, are explored. This is important to highlight as some indicators at the global level might not be applicable or not as relevant for Africa. As the IPCC Working Group 3 on mitigation does not carry out regional assessments, so the difference in indicators across scales is only available at present for the adaptation technologies. Future region- or country-specific assessments must consider their specific needs and contexts to adapt the indicators to meet their priorities. For example, for Central America, it might be important to incorporate Indigenous Knowledge under sociocultural indicators.

Figure 1. The multidimensional feasibility assessment of different mitigation and adaptation technologies

1. Define scope

Based on the scope of the study (global/national/local/sectoral) identify system transitions and underlying adaptation and mitigation technologies

2. Develop indicators

Across feasibility dimensions, develop indicators through literature review and expert elicitation

3. Create database

Conduct literature review for each adaptation technology at the indicator level

4. Conduct assessment

Assess each option at indicator-level giving scores for feasibility (high, medium and low), identifying where there is limited evidence (low evidence, no evidence), and where an indicator is not applicable

5. Check robustness

Cross-check each indicator-level score by 2-3 expert reviewers and adjust based on additional literature, regional diversity

6. Combine indicators

Combine indicator-level assessment (arithmetic mean of the relevant underlying indicators) to develop dimension-level score. The methods for combining the score is shown below.

7. Assess synergies and trade-offs

For adaptation options, assess positive or negative implications for mitigation

For mitigation options, assess positive or negative implications for adaptation

8. Report and visualise

Report dimension-level assessment through spider charts, traffic light tables etc. Differentiation of an option's feasibility diascussed in tables/text accompanying visuals

Calculating a score for each dimensions

High feasibility is weighed with a score of 3, medium feasibility with a score of 2 and low feasibility with a score of 1. This formula indicates, based on this weighing, how the composite feasibility of a dimension is obtained. The composite feasibility of an option, across dimensions, is calculated using the same weighing.

STEP 1

How many indicators in one dimension are effective (applicable)?

effective indicators = #indicators - #not applicable

STEP 2

How many indicators have sufficient litterature?

effective indicators - #NE & LE[6]

STEP 3

Average of the effective indicators with sufficient evidence[7]

$$\frac{(1*A + 2*B + 3*C)}{\text{\# effective indicators - \#NE \& LE}}$$

STEP 4

Assign category to dimension[8]

Legend of Feasibility Assessment Tables		Legend criteria for overall feasibility of each of the dimension-option combinations
Not applicable		All indicators are NA
Insufficient evidence		#NE & LE > 0.5 * #effective indicators
Low feasibility		AVG ≤ 1.5
Medium feasibilty		1.5 < AVG ≤ 2.5 #NE & LE ≤ 0.5 * #effective indicators
High feasibility		AVG > 2.5 #NE & LE ≤ 0.5 * #effective indicators

[6] NA: Non-Applicable, NE: No Evidence, LE: Low Evidence
[7] Low = 1, medium = 2 and high =3 A, B and C represent three hypothetical indicators.
[8] This approach was followed for the adaptation assessment. A similar assessment was followed for mitigation on enablers and barriers, but the dimensions are continuous rather than discrete.

Source: modified from Singh et al. (2020)

Table 3. Examples of indicators for technological feasibility for adaptation and mitigation technologies

Adaptation	Mitigation
Technical resource availability Are the technology and associated human, financial, administrative resources needed for an adaptation option available?	*Maturity and technology readiness* What is the level of R&D and time needed to implement the option?
Risk reduction potential Can the option reduce the likelihood and/or consequences of risks?	*Simplicity* Is the option technically simple to operate, maintain, and integrate?
	Technology scalability Can the option be scaled quickly to a meaningful level?

3.3 ASSESSING THE FEASIBILITY OF TECHNOLOGIES IN THE CONTEXT OF SYSTEM TRANSITIONS

This section shows the FA of selected technologies for agriculture, energy and water, drawing on the assessments from AR6 to highlight the different aspects of technologies and systems transitions and the links between adaptation and mitigation. To demonstrate the method, examples are drawn from two critical domains for technologies related to adaptation and mitigation, for energy and water:

1. Energy generation technologies, including those for renewable energy for mitigation (e.g. solar, wind and storage), water use management for mitigation and adaptation and reliable and resilient infrastructure for adaptation.
2. Water management as cutting across sectors and system transitions.

A synergies and trade-offs analysis is also presented for selected technologies for agriculture, water and energy. First, adaptation technologies are evaluated for their effect on mitigation. Then, mitigation technologies are evaluated for their effect on adaptation. The literature assessed as part of the FA is provided in the AR6 of IPCC Working Group 2 (supplementary material, chapter 18) and IPCC Working Group 3 (appendix 2 of chapter 6). Adaptation for agriculture, forestry and other land use and mitigation for energy are both highlighted as critical sectors that emphasize the nexus of energy-water-agriculture for Africa in section 4.

3.3.1 Feasibility of energy technologies

Mitigation for energy systems

Rapidly increasing the use of renewable energy technologies is the cornerstone of climate mitigation policy. The FA can provide crucial information – particularly beyond economic considerations – on where technologies have high feasibility, why this is the case, and where efforts are needed to remove additional barriers.

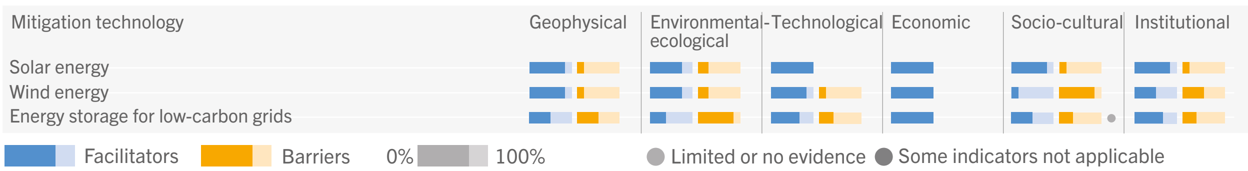
Figure 2 shows that at a global level many factors facilitate the implementation of solar and wind energy technologies. Specifically, these technologies are geophysically, technologically and economically feasible. Overall, solar energy is a feasible technology across almost all dimensions, but barriers, specifically related to land use, distributional effects, recycling and in some cases political support still need to be addressed. Solar energy faces few sociocultural barriers, as it is generally supported by the public, and has positive impacts on human health and well-being. However, high upfront costs may inhibit the adoption of solar photovoltaic technology (PV) for low-income individuals and communities, as well as in developing countries. The FA also shows that despite earlier concerns, solar energy has overcome initial institutional, legal and administrative challenges. However, political acceptance remains low in some countries due to opposition from vested interests such as electricity companies and possible competition for land use. Solar energy has beneficial environmental impacts importantly reducing air pollution by displacing fossil fuels. However, it often uses substantial amounts of land, and without strategies and policies to address the multiple uses for land, solar may threaten biodiversity and compete with agriculture and housing in densely populated areas. At the end of their useful life, solar PV panels can contribute to some toxic material waste, including the batteries in the case of stand-alone distributed generation systems. For other components, waste can be avoided by recycling the material, which is mostly glass and easily repurposed.

The FA indicates that wind energy (here, restricted to onshore wind) is a feasible technology across many dimensions. However, in contrast to solar energy, wind energy faces more sociocultural barriers – local wind parks can face public resistance and present justice concerns. The literature reveals that people often dislike the visual effect of wind turbines and parks on the landscape and report experiencing adverse effects on their well-being due to noise exposure and other dissatisfactions. Wind energy also faces institutional, legal and administrative challenges. Like solar energy, wind has beneficial environmental impacts by displacing fossil fuels, but can also compete with land use for other purposes. The operation of wind turbines produces little waste or pollutants. However, lifecycle impacts of wind turbines vary by operating lifetime, quality of wind resources, conversion efficiency and the size of the wind turbines.

Energy storage for low-carbon grids is important to ensure grid performance when relying more heavily on intermittent renewable energy sources. This example also highlights how an FA can be conducted for the overall feasibility of energy storage, as well as for specific types of energy storage technologies. The FA for energy storage reveals that the selection of the most feasible energy storage technology by application and location is critical for implementation. Concentrating solar power (CSP) technologies are very often combined with thermal energy storage which allows excess thermal energy to be stored, impacting positively on intermittence and contributing to reducing the costs of CSP power plants. Energy storage is economically viable and has few institutional barriers in some jurisdictions, but some of these barriers, namely legal and administrative issues, persist. Many storage technologies are already technologically viable, however some technologies, such as some types of batteries – e.g. metal sulphur and metal-air batteries – are still in early stages of development. Energy storage technologies can have high feasibility for land and geophysical resources as there is a wide range of storage technologies available that can be employed at different scales – e.g. large scale, small scale and modular. However, some types of storage require suitable land and geophysical resources that may not always be available in any given location or region. Moreover, energy storage technologies may have negative environmental impacts due to high water use, material extraction that may threaten biodiversity and waste disposal. In general, energy storage technologies are evaluated positively by the public, but there are some concerns about safety, costs and recycling possibilities.

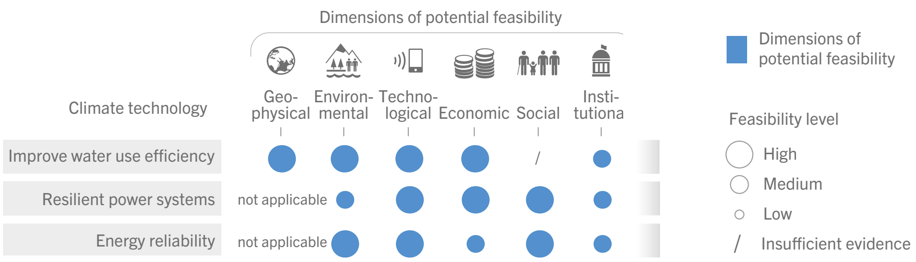
Figure 2. Feasibility assessment of energy adaptation and mitigation technologies

Panel A - Renewable energy mitigation technologies



Source: Based on Figure TS.31 from IPCC (IPCC 2022a)

Panel B - Adaptation technologies for energy systems



Source: Based on Figure SPM.4 from IPCC (IPCC 2022b)

Adaptation for energy systems

Climate adaptation is supported by enhancing the resilience of energy grids under extreme weather events and the provisioning of critical services and adjusting operations through water efficiency for energy generation technologies. The latter includes thermal, nuclear and hydroelectric generation which rely on water availability.

Critical infrastructure, networks and services – including generation, transmission and distribution – show a medium to high feasibility. However, like energy storage, the FA highlights the differences between technologies. Importantly, resilient power infrastructure includes distributed generation utilities, such as microgrids, as there is increasing evidence of their role in reducing vulnerability, especially for underserved populations. The energy generation technologies associated with resilient infrastructure, however, also consider all types of generation sources and transmission and distribution systems. Thus, the economic and technological dimensions are dependent upon the generation source and location of each specific generation plant. Also, while there is overall high sociocultural acceptability for these technologies, there is only medium institutional feasibility due to the absence of strong policies for resilient infrastructure. Furthermore, these technologies are not sufficient for the deeper transformations required for mitigation in the energy sector which requires a focus on technological transitions from a fossil-fuel to renewable energy systems.

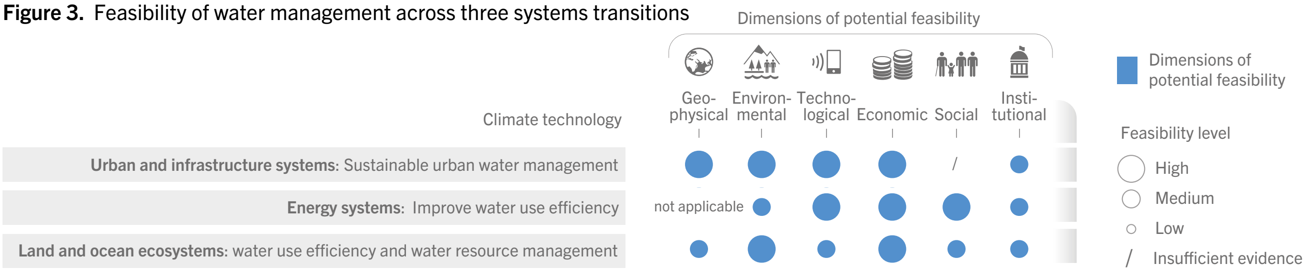
The reliability of power systems also has high feasibility in the technological and social dimensions. There are multiple ways of enhancing reliability by engaging with the supply and demand aspects of the energy sector. Here, the focus is primarily on creating redundancy in and hardening power generation, transmission and distribution systems during extreme weather events. This may range from diesel-powered backup generators to the use of solar power and storage for local use to ensure the continuity of telecommunications during power outages. Importantly, the implementation of these redundancies ensures the continuous functionality of emergency services – such as communications, health and water pumping, among others – in urban, peri-urban and rural landscapes. There is also high feasibility for the economic and sociocultural dimensions – with the latter being more prominent in decentralized systems – and medium feasibility for institutional and geophysical dimensions. The adaptation FA also highlights that some indicators, especially within the institutional, social and geophysical dimensions, have limited evidence as they have not been the focus of dedicated research. For example, when discussing the social co-benefits of reliable energy systems and efficient water use, the literature does not focus on intergenerational or gender issues separately from the broad range of social co-benefits. In these cases, the FA can also suggest where decisionmakers may want to take care to monitor and evaluate outcomes in their implementation.

Feasibility of water use management

Water use management cuts across mitigation and adaptation as well as sectors and systems. For example, water management in energy systems focused on water efficiency and cooling apply to many types of generation sources, as well as reliable power systems. This technology has high feasibility for economic, technological and environmental dimensions. Water management is well established, and efficient water use can make power generation options more efficient and cost-effective. It can also have positive effects on the environment, especially in drought-striken regions. There is also high political and medium sociocultural acceptability. Reducing water usage is captured in the environmental feasibility of mitigation technologies and thus, as reducing water usage for energy can provide multiple benefits, environmental feasibility for water management for mitigation is high.

In Figure 3, the feasibility of adaptation technologies related to water are shown. The key constraint across water management technologies is institutional. Enhancing institutional support from governments can improve sustainable water management, and it is otherwise medium or high feasibility on the other five dimensions. Some forms of governance can also enhance local stewardship and social inclusion, For example, informal settlement residents can be included in governance arrangements, such as watershed stakeholder dialogues. Figure 3 shows the difference in the feasibility of water options across three system transitions.

Figure 3. Feasibility of water management across three systems transitions



Source: Based on Figure SPM.4 from IPCC (IPCC 2022b)

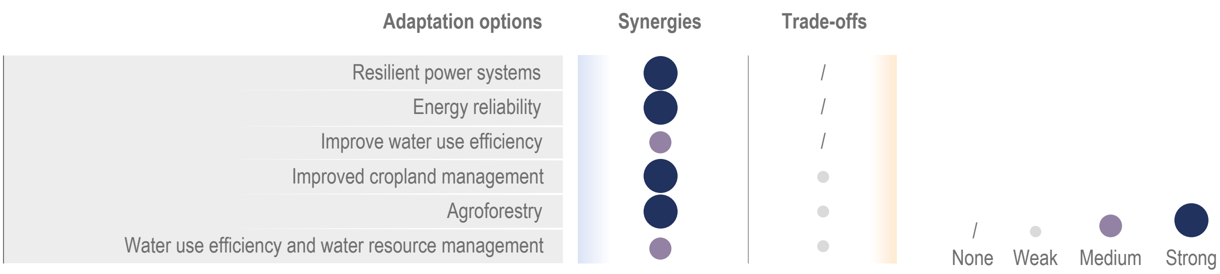
Synergies and trade-offs

An FA also provides an assessment of the synergies and trade-offs between adaptation and mitigation and with the SDGs. This is important as, for example, there are mitigation options that can increase the risks associated with increased land and water use and can create competition with land and water use for food or human consumption. Similarly, there can be adaptation technologies that may have high feasibility, but which would increase greenhouse gas emissions, such as the use of air conditioning. The synergies and trade-offs assessment helps expand the FA to analyze these additional interactions. This is especially important when the analyses of mitigation and adaptation are not linked or where there is a pressing need to focus on adaptation or mitigation only.

Figure 4 provides a high-level summary of the insights possible through an analysis of synergies and trade-offs across the FA. A wider summary is presented in annex C. In figure 4, it is observed that reliable power systems have strong synergies with mitigation. For climate adaptation, the full range of energy technologies are considered – i.e. the energy technologies were not limited to low-carbon options. Solar energy, wind energy and energy storage for low-carbon grids could also support climate adaptation, primarily through technologies for resilient power infrastructure. In this way, adaptation and resilience could present trade-offs with mitigation. However, the high feasibility of the renewable technologies could also support their use for adaptation, leading to high synergies. Assessing the joint application of renewables and resilient power grids with synergies for adaptation and mitigation more completely, however, would require an integrated FA with the combined literature.

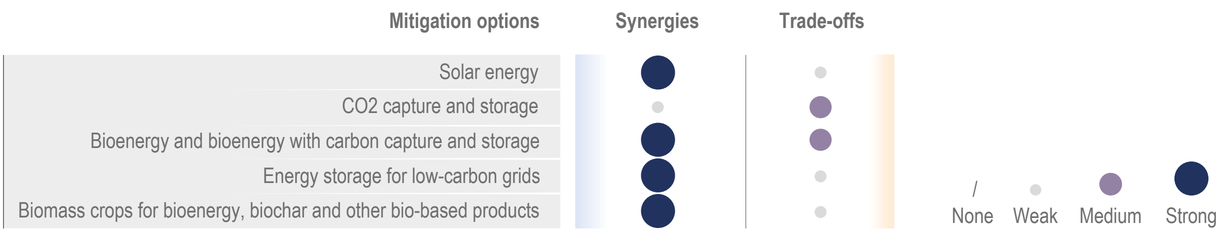
Figure 4. Synergies and trade offs

Panel A: Implications for Mitigation



Source: Based on Figure FEASIB 4 from IPCC (IPCC 2022b)

Panel B: Implications for Adaptation



Source: Based on Figure FEASIB 4 from IPCC (IPCC 2022b)

3.4 APPLYING THE FEASIBILITY ASSESSMENT IN AFRICA

3.4.1. Context for feasibility assessments for Africa

There are both substantial opportunities and pressing needs for adaptation and mitigation technologies in Africa.

When conducting FAs at a regional level, both dimensions and indicators from the global level generally require modification, as is shown here for Africa. For example, the geophysical dimension was modified into an indicator as part of the broader environmental dimension as there was insufficient distinct literature on geophysical factors separate from environmental factors.

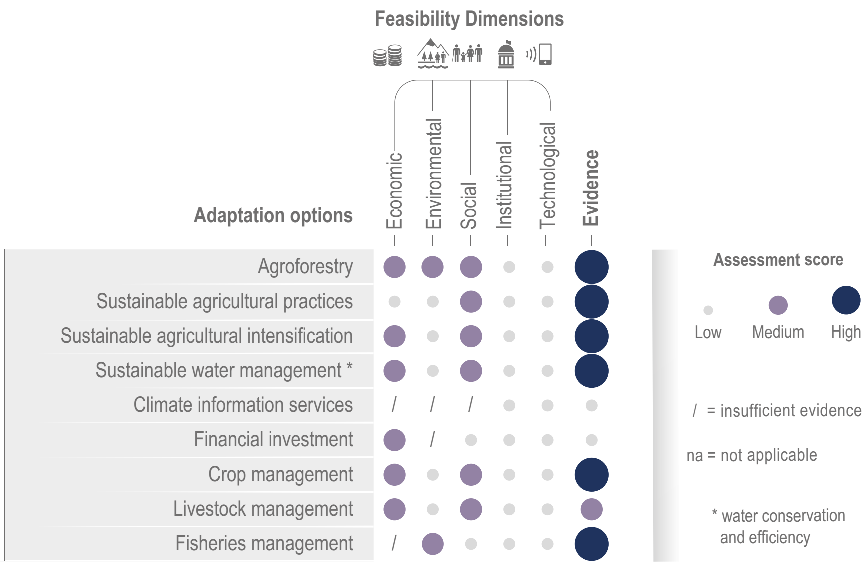
While some of the modifications in dimensions and indicators show the flexibility of this approach to adjust to context and user and decisionmakers' needs, the fewer dimensions compared to the global FA also reflect the evidence base for Africa. For example, due to the limited studies on adaptation in Africa on some economic indicators, the employment and productivity potential indicator was modified to become economic co-benefit. To further address gaps in the information for Africa, a structured expert elicitation process was proposed to assess how the outcomes of the IPCC assessment resonated with the African context. While this exercise was not conducted in the

IPCC report, this is an important priority for subsequent FA efforts, and this is revisited in the recommendations.

3.4.2 Feasibility assessment of select adaptation technologies in Africa

Figure 5 shows the results of the FA for nine adaptation options: agroforestry, sustainable agricultural practices, agricultural intensification, sustainable water management – conservation and efficiency, climate information services, financial investment in agriculture, crop management, livestock management and fisheries management.

Figure 5. Feasibility assessment of agricultural technologies for adaptation in Africa



Source: Based on Figure 9.7 from IPCC (IPCC 2022d)

The FA highlights the need to focus on both technological and institutional dimensions to enhance implementation. Technological barriers include the limited availability of and access to weather and climate data for timely decision-making. Technological barriers, in terms of the adequacy of infrastructure, were identified in north and west Africa. High institutional barriers were another major concern for most adaptation technologies assessed. Institutional aspects include legal frameworks, governance and policy or local rules affecting adaptation. It also involves enabling conditions for implementation, whether current political, human capacity and legal conditions allow for the implementation of the option. This assessment also reveals the paucity of data in the existing peer review literature to assess feasibility, indicating that the knowledge gaps may also be hindering implementation of agricultural adaptations in Africa.

3.4.3 Feasibility assessment of mitigation technologies for energy in Africa

With abundant and diverse renewable energy potential there are substantial opportunities for mitigation technologies across Africa. However, these resources are largely unexploited (African Energy Commission [AFREC] 2019). In Working Group 3, a FA was only conducted for mitigation technologies at a global level and thus, compared to adaptation, less detail is available. However, drawing from the systemic literature review conducted for a global level assessment of mitigation technologies, some initial observations can be distilled for feasibility in an African context. Three key factors that can be used to evaluate feasibility are the resource potential, land-use and land-use trade-offs and economic viability with sufficient information for three technologies – solar energy, hydroelectric power and bioenergy.

All three technologies perform well on resource potential and economic viability. Land-use and the trade-offs between allocating land for energy rather than other productive uses – namely agriculture – can affect feasibility across Africa. Hydroelectric power faces specific challenges due to the large footprint associated with the infrastructure and reservoirs. A further analysis by region in Africa reveals variation on these factors. For example, higher barriers may exist in north Africa for hydroelectric power due to more limited resource potential. This analysis also highlights that these assessments need to extend beyond the peer review literature, including the use of expert elicitation to draw upon the knowledge of practitioners and officials.

3.5 CONCLUSIONS AND RECOMMENDATIONS

Using the systematic methodology of the FA provides a reproducible and transparent approach for looking at technologies and drawing upon as much evidence as possible. In this way, a decision maker should gain confidence in the overall assessments of levels of feasibility for many climate technologies. The FA is also a flexible approach that allows for regional differentiation on the dimensions that comprise feasibility. The scale of the assessment influences the relevant dimensions. For example, for global assessments, such as those of the IPCC, which necessitate some degree of generalization and consideration of their associated interactions. Through the FA for Africa, this report also highlights how feasibility are context-dependent and may vary between different social groups and locations. In carrying out these additional approaches, the specific indicators under each dimension may vary to reflect priorities and expectations. For example, in some rural communities or when related to Indigenous Peoples, the inclusion of an indicator specific to Indigenous Knowledge might be necessary. Finally, there is the potential to extend the indicators to consider the integration of climatic and non-climatic stressors, as in practice these stressors are often coupled.

The FA by technology – particularly emphasized by those for Africa – show how this approach can identify knowledge gaps where more research is needed to understand the implications of certain technologies. The results shown in this scoping report reflect the synthesis of the information in the peer review literature as defined by the IPCC mandate. Applying expert consultations with stakeholders, rights holders and users of the technology or technologies, and using grey literature in the FAs would be an important innovation in order to implement these analyses at a regional and country level, which have the benefit of more fully capturing the local context.

This FA should also be understood as a snapshot of the feasibility on an indicator at the time of the analysis. However, feasibility is also temporally dynamic. Moving from a static assessment to a more dynamic understanding of how multiple factors change overtime and interact to shape and change overall feasibility could be a key outcome of the annual series of climate technology progress reports. Such repeated assessment may also reveal how feasibility is enhanced across time, which provides important insight in how to improve feasibility in other contexts. In this way, the FA inform and open pathways that better align how capital and resources are allocated and support more rapid climate action.

Part B

4.

Governance: Institutions, policies and social dimensions

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4.1 INTRODUCTION

Understanding and supporting enabling environments are critical steps in successfully developing and transferring climate technologies for low-carbon and climate-resilient development (IPCC 2022b). However, the development and transfer of climate technologies (such as clean cooking stoves, solar PV, bioenergy crops, early warning systems, water management technologies, efficient irrigation systems and climate-resilient infrastructures) encounters multiple challenges that affect the development and transfer of such technologies into national socio-economic contexts.

Creating an enabling environment for the development and transfer of climate technology solutions requires an understanding of the social, political, institutional, regulatory and financial dimensions that underpin the capability of national actors to manage innovation and technological change (TEC 2022). At the same time, supporting national enabling environments is highly interlinked with the international climate policy processes, particularly the UNFCCC, where policymakers seek to improve international technology cooperation and effectively mobilise resources and capacities for technology development and transfer.

Mobilising climate technology development and transfer in developing countries requires effective governance structures and arrangements that support enabling conditions. These stipulate paying attention to clear modalities and procedures of how technology options are selected by countries, how the views of technology users and providers are addressed and how the interaction between different actors is developed and coordinated over time (McGee and Wenta 2014; Ockwell and Byrne 2016).

Chapter 4 focuses on understanding progress in the enabling environments supporting climate technology development and transfer. While the ambition of this report is to have a global scope going forward, the focus of this chapter this year is mainly on governance in the context of developing countries. For this purpose, the chapter characterises context and enabling environments, providing illustrative cases and analysing recent survey data collected from African countries to draw lessons on social, political, institutional, regulatory and financial dimensions. The final section of the chapter presents a summary of results and recommendations for improving the governance of enabling environments for climate technology development and transfer moving forward.

4.2 CONTEXT AND ENABLING ENVIRONMENTS

Climate change threatens to hinder social and economic opportunities and is likely to cause irreversible damage to critical ecosystems and compromise climate-resilient development (IPCC 2022a). Consequently, countries are under pressure to advance mitigation and adaptation efforts and do more to address climate change while pursuing alternative, low-carbon economic development pathways that are socially inclusive and environmentally sustainable (Green and Gambhir 2020; Sovacool et al. 2020). Although the international policy community has pledged financial support, fostering enabling environments capable of promoting climate technology development and transfer in developing countries remains a significant challenge given the lack of institutional and economic capacity for transition to climate-resilient development (Guzmán et al. 2022).

Many governments in developing countries require support to build the capacities needed to effectively benefit from international climate finance, which is heavily focused on technology transfer models that depend on accessing large amounts of capital for de-risking technological investments (Colenbrander et al. 2021; Polzin et al. 2021). While market-based solutions are important for securing effective long-term technology transfer mechanisms at a global scale, several gaps exist in enabling the appropriate and sufficient allocation of financial resources to meet developing countries' needs in the short term. For example, the cost of accessing capital for climate technology solutions such as renewables remains high (IRENA 2020) and the challenges for adaptation financing are even higher (Thomas, Serdeczny and Pringle 2020; UNEP 2021). This poses additional challenges to enabling technology development and transfer for climate mitigation and adaptation.

It is also the case that developing countries are advancing science, technology and innovation plans to strengthen their innovation systems for a more coordinated response to technological innovation in the context of climate change (Anadon et al. 2016). However, while technological innovation offers many opportunities for climate-resilient development, unless enabling conditions are properly addressed at the country level, such innovation creates barriers to cross-boundary technology cooperation and transfer (TEC 2022). Creating enabling environments therefore requires more than just developing modalities for technology development and transfer. Wider and context-specific dimensions that converge and are part of innovation processes at the country and international levels also affect the development of such environments. These enablers are characterized below to give a sense of the capabilities needed to coordinate and govern action on technology transfer between national and international actors.

4.2.1 Policy dimension

Effective policymaking is essential in establishing enabling environments for the development and transfer of technologies to support climate change mitigation and adaptation (de Coninck and Puig 2015; de Coninck and Sagar 2015; Olhoff 2015). Policy influences the development and transfer of different types of technologies through a variety of mechanisms (Lema and Lema 2012). For example, the uptake of technologies, such as irrigation or solar home systems, in the private market is predominantly influenced indirectly by politically mediated market conditions, while the uptake of publicly available technologies is influenced directly through political decisions taken by governments and public entities on the implementation of specific technologies, such as mass transportation or coastal protection technologies (Linham and Nicholls 2010; Ruckelshaus et al. 2020). In this way, policies that are designed to address barriers to technology diffusion and are aligned with national socioeconomic needs may help build synergies for a better and more coordinated response to technology transfer. Developing countries formulate and implement climate policies that aim to develop their nationally determined contributions (NDCs) and target climate finance potential for climate technology projects. However, technology policies do not exist in silos, and must be integrated with other national policy priorities, for example, by increasing coordination with stakeholders developing science, technology and innovation policies. Engaging industries, academia and wider society is a critical factor in enabling and accelerating climate action (TEC 2015).

4.2.2 Legal and regulatory dimension

In the context of climate technology development and transfer, good regulatory frameworks can act as enablers by reducing inefficiencies and supporting the capacity to reinforce good administrative practices and governance for more responsible and dedicated innovation, technological deployment and diffusion actions (Kowalski, Rabaioli and Vallejo 2017; Stilgoe, Owen and Macnaghten 2013). Responsible regulation can help reduce investment and social risks and build confidence by clarifying the expected outcomes of innovation and technological change for governments, businesses and wider society. While regulatory frameworks offer many benefits in support of technology transfer, they also bring practical challenges that need to be addressed (IPCC 2022). These include finding the appropriate balance between regulatory reforms at the country level, and promoting innovation, including building capacity between economic, social and institutional dimensions affecting climate technologies. Regulatory reforms should not be aimed exclusively at economic and financial aspects, but also cover the contribution of scientific and technical knowledge and the provision of intellectual property rights and ownership (Van Kerkhoff and Szlezák 2016). A key issue in innovation policy that informs technology regulation is who owns the outcomes of innovation, such as technologies, products and services (Abdel-Latif 2015). This requires governments to play an active role in creating enabling environments through establishing or reforming legal and regulatory frameworks that stimulate technological innovation (UNFCCC 2020) in ways which ensure the risks and reward are shared among public and private actors (Mazzucato 2016). In the context of technology development and transfer, regulatory functions should focus on directing system-level reforms that stimulate technology demand, incorporate international best practice, and deal with official development assistance conditionalities, intellectual property right regimes and the technology cost of capital. Taken together, these represent some of the key underlying challenges of the competitive structures across different sectors for both mitigation and adaptation technologies.

4.2.3 Institutional dimension

For the purpose of this report, institutions are defined as rules, norms and conventions that guide, constrain or enable human behaviours and practices. Institutions can be formally established, through laws and regulations for example, or informally established, through traditions, norms or customs. Institutions may spur, hinder or strengthen the emergence, adoption and implementation of climate action and climate governance (Croxatto, Hogendoorn and Petersen 2020; Scoones et al. 2020; Young 2017). Following this perspective, technology development and transfer involve a social process of interaction between actors and institutions and the mobilization of specialized knowledge and resources to facilitate the diffusion and adoption of technologies from one context to another. Institutions also refer to financial, judicial and regulatory systems, as well as the wider innovation system embedding engineering practices, technology production, skills and procedures (van de Wetering, Mikalef and Helms

2017). The different elements comprise complex institutional systems whose uses and practices must be understood, since these are highly context-specific. A deeper understanding of institutional enablers makes it possible to analyse systemic social and technical configurations to remove barriers and allow new institutional configurations to develop in favour of climate technology development and transfer (TEC 2022). To speed up the implementation of the Paris Agreement with regards to technology, there are opportunities for strengthening institutional cooperation between a range of stakeholders, including the public and private sectors, wider society, financial institutions, non-governmental organizations and research institutions (TEC 2022). Since the development and transfer of technology involve cooperation at various levels of governance, institutionalizing human skills, recourses and practices in organizations is critical to enhancing feasibility and opportunities.

4.2.4 Social dimension

In the context of technology development and transfer, the social dimension of enabling environments refers to systems in which organizations and their institutions play a major role. Social dimensions include civil society, networks and social processes related to technology, including the production and consumption of technology, as well as lifestyles, preferences, habits and cultural traditions related to techniques and tools but also reflecting world views (Crewe and Axelby 2013; Moore et al. 2018). Technology is socially constructed (Bijker, Hughes and Pinch 2012), and the production and use of technologies encompass wider social, cultural, moral and political processes which are not value-free and require careful consideration of context, place and the communities where historical factors and social context play a crucial role in enabling or hindering development, innovation and technological change (Crewe and Axelby 2013). To understand socially enabled conditions for the development and transfer of climate technologies in developing countries, it is important to consider issues of participation, particularly for those directly affected by climate impacts, such as indigenous people and local communities. It is also vital to take gender perspectives seriously and identify their roles as essential components of social enablers and development. In practice, the social dimensions of enabling environments are heterogeneous by nature and typically anchored in context-specific relations and complexities surrounding knowledge, beliefs, laws, customs, practices and local capabilities acquired by humans as members of a particular society and culture.

4.2.5 Financial dimension

Climate finance refers to local, national and international financing from public, private and alternative sources that seek to support mitigation and adaptation actions that will address climate change (Watson and Schalatek 2019). To successfully mobilize climate finance for the development and transfer of climate technologies, there are challenges and drivers that need to be considered at country level (Reutemann 2018; TEC 2015) Starting from the recognition that the level of financial contribution countries can make to climate change action, as well as their ability to cope with climate impacts, varies significantly (UNFCCC 2022), there is a widely shared consensus that climate finance is needed for mitigation because large-scale investments are required to reduce greenhouse gas emissions while pushing for economic growth. There is less agreement around how to finance climate change adaptation due to uncertainties about the potential benefits and confidence in the levels of risk involved and the difficulty of estimating climate impacts ex ante. This is typically reflected in the fact that technologies are often associated with high capital costs when investment in technology is deemed risky (Ameli et al. 2021). However, climate finance for adaptation is equally important, as it is likely that significant resources will be required to equip developing countries with climate technologies that they can use as tools to help them adapt to the adverse effects of climate change and increase their resilience(UNFCCC 2022). It is the responsibility of developed countries to facilitate access to finance for the development and transfer of technologies, including a wide variety of sources, instruments and channels, and to support developing countries to implement country-driven mitigation and adaptation strategies (TEC 2015). Investment in developing and transferring climate technologies must therefore come from diverse stakeholders, including the private sector. However, public finance is a critical catalyst for attracting private capital, and is needed to lower the risk involved in climate technology development and transfer from international to national levels (TEC 2015).

4.3 WHAT ENABLES SUCCESS

This section provides two illustrative cases of enabling environments for climate technology development and transfer in East Africa. Case 1 (Box 1) illustrates climate change mitigation and the development of co-benefits through enabling clean cooking in Uganda. Case 2 (Box 2) shows how enabling conditions improve adaptation through water access and enhance climate resilience in response to climate-induced droughts using sand dams as a climate-adaptive technology in Kenya.

Box 2. Case: Enabling clean cooking in Uganda

Despite historically low electrification rates in Uganda, cooking with electricity is now becoming a viable and scalable option. According to the Ministry of Energy and Mineral Development (2020), 24 per cent of households have access to grid electricity. However, Uganda today also produces surplus electricity amounting to almost double the current demand. Over the last 10 years, the total installed generation capacity has doubled from 600 MW to 1,200 MW. The sector has expanded from three power plants in 2001 to over 40 in 2020. Years of investment in power generation capacity and a dynamic economy underpinned by strengthened and enabled institutional frameworks contributed to this achievement through removing investment barriers and promoting subsidies. This investment has also helped the sector to build resilience and reduce the country's dependency on hydropower plants vulnerable to drought-induced power outages, and increase social acceptance. The utility company is also one of the few in Africa that is said to be recovering its operational costs from revenue collected (Kojima and Trimble 2016). However, increasing generation capacity is an expensive undertaking for two reasons: first, power plants are built with borrowed money and public debt has to be paid off; second, the take-or-pay clause in power purchase agreements means generated power must be paid for, even if there is insufficient demand. Experts warn that this could lead to higher costs per kWh for users (Godinho and Eberhard 2019). The cost of electricity in Uganda is already relatively high at USD 0.20 per kWh. This means the value households derive from electricity access is limited due to the perceived high cost of electricity.

At the same time, unprocessed biomass and charcoal currently make up over 95 per cent of the fuel used for cooking nationwide (Energy Sector Management Assistance Program 2019). Liquefied petroleum gas (LPG) and electricity make up the rest. In urban areas, charcoal demand will likely increase rapidly over the next few decades due to population growth and urbanization. This is expected to exacerbate the problem of environmental degradation. The Government is therefore proactively working to stimulate social enablers, for example by stimulating demand for the use and adoption of modern energy services like electricity and LPG by providing a stable and predictable business environment. The National Development Plan III (NDP III) is committed to increasing access to and consumption of clean energy, and to reducing over-reliance on biomass by enabling investment opportunities in energy-efficient technologies. Furthermore, the National Energy Policy Bill (currently under review) outlines a plan to incentivize households to switch to clean and modern cooking technologies. Under the purview of the Electricity Regulatory Authority, through flagship programmes such as "Charcoal to Power" and "Cooking Tariff" the Government is also enabling fiscal policies and regulatory systems to develop, and incentivizing and promoting easier access for households to affordable power, keeping demand active while easing the socioeconomic burden of access to energy (Energy Regulators Association of East Africa 2022).

Woman buys charcoal at a market in Kampala, Uganda.
Vlad Karavaev, Shutterstock

Box 3. Case: Enabling sand dams as a climate-adaptive technology in Kenya

Climate change has aggravated soil erosion in semi-arid areas of Kenya, and large volumes of sand are deposited in rivers. Sand is excavated during the dry season and is, according to UNEP, the second most exploited resource after water. Unregulated sand mining is leading to environmental degradation and loss of grazing areas, and is causing serious social conflict between sand harvesters, powerful business cartels and the local population. In this context, local government regulation of sand harvesting, combined with the construction of sand dams and seepage wells, has proven a successful technology for increasing resilience, reducing the vulnerability of natural and human systems, and improving their adaptive capacity (Boko et al. 2007; Adger et al. 2007; Nissen-Petersen 2007).

For a long time, even prior to the local government reforms embedded in the 2010 Kenya Constitution, local governments in the country have benefited from a predictable, enabling business environment and from the taxation of sand mining. However, while most local governments primarily focus on sand mining as a source of revenue, a few local governments, like the Makueni County government, have taken a different path, emphasizing environmental protection and regulatory systems as enablers for responsible sand mining (Mohamed Daghar 2022). In 2015, Makueni County enacted a Sand Act and then in 2017 established Makueni County Sand Conservation and Utilization Authority (MCSCUA) to regulate sand utilization, including sand accumulated by sand dams. MCSCUA functions as an independent authority that issues permits and charges fees for the commercial extraction of sand and clean drinking water. The agency has succeeded in creating enabling conditions, such as being economically self-sufficient while enforcing sustainable natural resource management. The Sand Act (Section 35) stipulates that 50 per cent of the collected fees are to be placed in a conservation fund that has financed the construction of 21 sand dams in the county since 2017. These are used for domestic use, growing animal feed, irrigation, sand harvesting and tree planting. Through inclusive governance and the establishment of an independent agency focused on conservation, the Makueni County local government has struck a good balance between sustainable natural resource management and generating income from the extraction of sand, thus ensuring social benefits for the adjacent local population.

Overall, Case 1 illustrates the importance of enabling environments such as providing appropriate institutional frameworks, removing barriers to investment, promoting subsidies, improving the social acceptability of technology, expanding energy access and increasing social demand for clean, energy-efficient technologies. Case 2 illustrates how enabling conditions such as economic self-sufficiency and inclusive governance can lead to sustainable resource management, water adaptation practices and the provision of social benefits for local communities.

4.4 SURVEY RESULTS: OVERVIEW OF PROGRESS ON ENABLING ENVIRONMENTS IN AFRICA

The analysis presented in this section utilizes data from a survey of government officials in African countries on the enabling environment in their country for specific climate technologies (see Chapter 2 – Approach for details and indicators). The following themes drawn from an analysis of the survey offer a snapshot of progress on climate technology based on the responses of government officials from 22 African countries.

Moderate progress has been made in creating enabling environments for the adaptation and mitigation technologies assessed, with marginally more progress for adaptation technologies. The average scores assessed across all enabling environment indicators were 2.9 out of 5 for adaptation technologies and 2.8 for mitigation technologies. While the overall enabling environment for adaptation technologies was reported as being marginally more advanced than for mitigation, there was significantly more progress in five indicators: integration of the climate technology into economic and financial policy and sustainable development policy; the degree to which institutional structures have been set up for the technology; the degree to which laws and regulations have been established and enforced for the technology; and the degree to which funds have been allocated from the national budget to support the technology.

Progress is relatively consistent across dimensions but uneven within each individual dimension of the enabling environment for the adaptation and mitigation technologies assessed. Moderate progress has been made across the policy, institutional, legal and sociocultural dimensions for the technologies assessed, but significantly less progress has been seen in the financial dimension. The policy dimension provides an example of the uneven nature of progress within dimensions. Respondents assessed that climate technologies were well integrated into national climate change policies but significantly less integrated into education, training and innovation policies, or broader policy frameworks at the sectoral or subsectoral levels. A notable exception is that respondents assessed good progress in links between climate technology policy and sustainable development objectives for adaptation technologies. The unevenness of progress within dimensions is also evident in the institutional dimension. Here, respondents assessed a high level of engagement by public and private sector institutions in technology development and transfer. By contrast, respondents assessed that formal institutional links between technology policymaking and industry, markets and the private sector were significantly lower than the average for mitigation technologies and the institutional dimension.

Figure 6. Average scores assessed for indicators in the institutional and legal dimensions of the enabling environment for adaptation and mitigation technologies

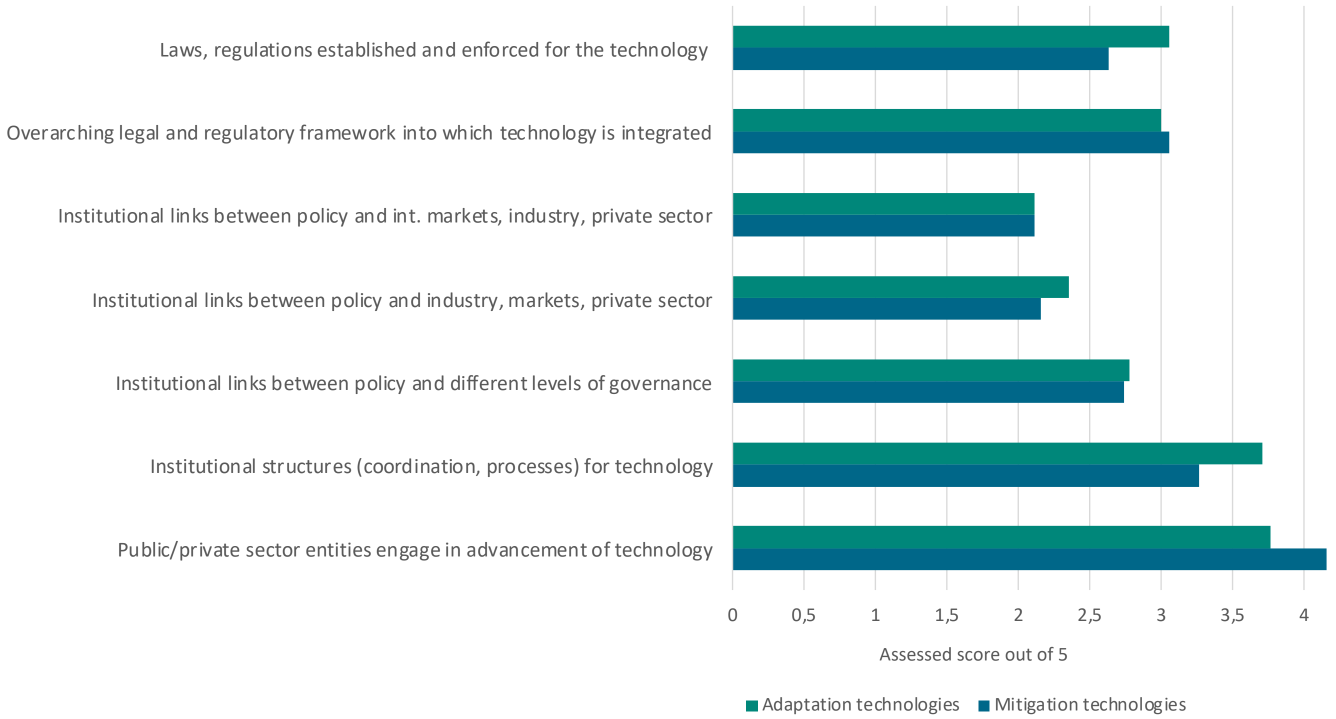
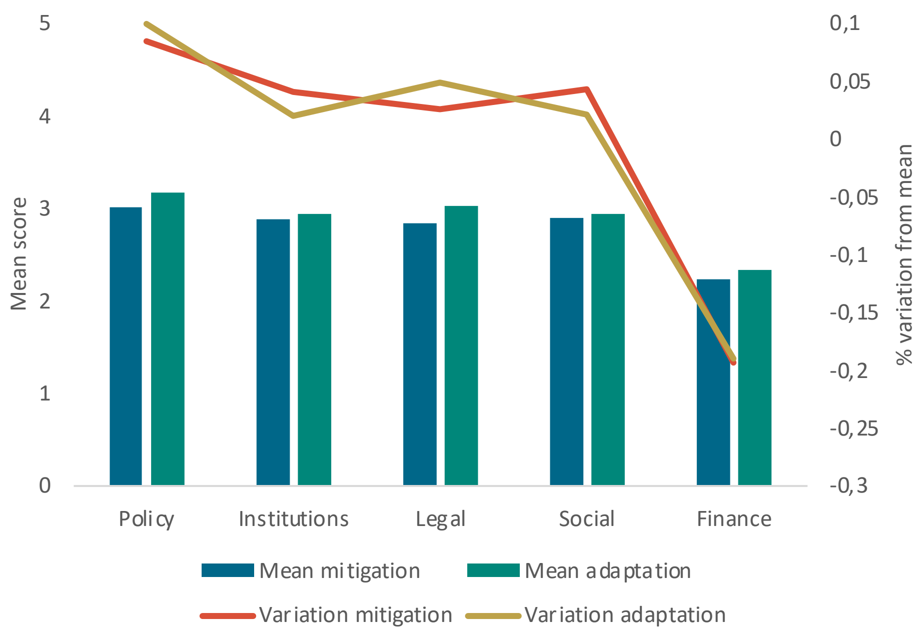


Figure 7. The bar chart illustrates average scores for the adaptation and mitigation technologies assessed within five dimensions of the enabling environment. The line chart illustrates the variation of individual indicator scores within each of the five dimensions



Connections across closely related aspects that occur in different dimensions can be enhanced. Respondents assessed that progress was uneven across indicators connected to finance. For example, respondents considered that progress differed in terms of funding from national budgets, developing links to international sources of private and public funding, and implementing economic and financial policies. Respondents also assessed that progress was uneven across indicators measuring engagement with the private sector. For example, respondents considered that there was good engagement from the private and public sectors in developing and taking up technologies. However, respondents assessed institutional links between the policy on specific technologies and the private sector at the national and international levels to be significantly less advanced than institutional links to global sources of private sector funding. What is more, respondents assessed that users, consumers, lifestyles and preferences play an influential role in shaping the advancement of the assessed technologies. However, respondents rated as low the degree of progress in establishing civil society institutions, networks and processes to support adaptation and mitigation technologies. Finally, respondents felt that little progress had been made in establishing and implementing communication campaigns for climate adaptation and mitigation technologies.

Limited progress is being made in the financial dimension. Respondents assessed finance as the least advanced dimension for both adaptation and mitigation technologies, with scores on all four indicators significantly below the average for all indicators. Notably, respondents assessed the provision of funds from national budgets as the area where least progress had been made, with progress on mitigation technologies assessed as significantly lower than on adaptation technologies. Moreover, a very high proportion of respondents gave this indicator the lowest score for adaptation and mitigation technologies (proportionately more for mitigation), although there were some notable exceptions. Respondents assessed that significantly more funds had been allocated from national budgets for adaptation technologies than mitigation technologies. Finally, respondents assessed that funding from industry, markets and the private sector was low, as were efforts to establish links between policy and international sources of public and private funding.

Progress in the enabling environment across different mitigation technologies is uneven. Respondents assessed differing levels of progress in the enabling environments for different mitigation technologies (based on an analysis of small-scale solar technologies). In the case of small-scale solar technologies, respondents assessed that the overarching legal frameworks were significantly better than for mitigation technologies, as were the establishment and enforcement of regulations for the technology (the latter indicator was assessed as very low for both adaptation and mitigation technologies).

Progress in enabling environments is not even across countries. There was a wide range of scores across countries. For adaptation technologies, the lowest average score for all indicators was 2 out of 5, and the highest average score was 4.7. For mitigation technologies, the lowest average score for all indicators was 1.6 out of 5, and the highest average score was 4.3. There was also significant variation in assessments for individual indicators. Respondents were split on the degree to which technologies have been integrated into national climate change policy. Several countries assessed a score of 5 out of 5 for this indicator. However, a significant proportion of respondents also scored this indicator 1 out of 5. Respondents were similarly split in their assessments of funds made available from national budgets, with a significant proportion of respondents assigning a score of 1 out of 5, but others giving relatively higher scores. In addition, those respondents who assessed high scores for specific indicators did not necessarily assess those same high scores for other indicators.

International policy support is having more impact in some areas than others. Respondents assessed relatively high scores for integrating adaptation technologies into sustainable development policy but significantly lower scores on the same indicator for mitigation technologies. Interestingly, some respondents assessed a high degree of integration for adaptation technologies, but a higher proportion assessed low scores. This separation was evident across all mitigation technologies, particularly for small-scale solar technologies. Institutional links between policy on climate technologies and international public sources of finance were rated as below average for both adaptation and mitigation technologies, despite international support such as the Green Climate Fund's Readiness and Preparatory Support Programme and the institutionalization of National Designated Authorities (NDAs). In addition, many respondents assessed the lowest scores for mitigation technologies.

Limited progress has been made in integration with sustainable development, including the inclusion and role of women, indigenous peoples and local communities. Respondents assessed very low progress in links between technology policy and indigenous peoples and local communities for both adaptation and mitigation technologies. Notably, a high proportion of respondents assessed the lowest scores for this indicator. Furthermore, respondents assessed links between technology policy and gender perspectives as slightly below the average indicator score for adaptation and mitigation technologies.

4.5 CONCLUSIONS AND KEY MESSAGES

Climate technologies are essential for advancing low-carbon, climate-resilient development pathways in developing countries, but only insofar as resources and capabilities are available to the stakeholders who are engaged in making decisions and implementing climate technology programmes and projects. Many of the technological capabilities found in countries are contingent on coordination between public and private actors, and on technology stakeholders having the capacities needed to catalyse finance for climate technology development and transfer into their national socioeconomic contexts.

Results from the survey conducted with African stakeholders shows steady progress as well as areas where significant improvements are needed. Overall, African stakeholders perceived that moderate progress is being made in establishing enabling environments for mitigation and adaptation technologies. However, this is overshadowed by the relatively uneven distribution of progress across the enabling dimensions assessed, with particularly limited progress on finance for climate technology development and transfer.

It is important to recognize that enabling environments are context-specific and diverse, according to each country's needs. They should not be generalized. The findings presented in both case studies and the survey in this chapter suggest the following messages:

a) **Address more complex and nuanced elements when dealing with enabling environments**. These include efforts on understanding culture, gender, identity, institutional settings, policy and regulatory regimes, human capacities, processes for accessing resources and capital, issues of national ownership and national strategies for science, technology and innovation. They all require in-depth quantitative and qualitative assessments at country level.

b) **Continue to strengthen enabling environments by considering further how such enablers apply to developing country contexts**. For example, African countries are politically, socially and economically diverse. Their aspirations, needs and capacities for meeting climate-resilient development will vary, and these differences need to be taken into account.

c) **Pursue efforts to innovate around strategic dialogue and stakeholder engagement and partnerships to improve enabling environments for effective development and transfer of climate technologies**. For example, African governments and international donors could develop dedicated strategic alignment conversations specifically aimed at linking global climate technology development and transfer processes to national NDCs and other relevant national policy priorities and development needs, including those identified in the SDGs.

d) **Take urgent action to ensure access to balanced climate technology financing, a significant challenge**. In this respect, the international policy and financial community continues to prioritize mitigation actions over adaptation financing for climate technology transfer. African countries are already constrained by the lack of adequate access to finance, which is a clear and significant barrier that must be rapidly addressed to generate enabling conditions that will support further progress on integrating climate technology policies with sustainable development policies at the national level and scale up climate efforts related to technology and financing for mitigation and adaptation.

e) **Support strong and transparent governance to foster enabling environments for the development and transfer of climate technologies in developing counties**. This should facilitate both private and public interests in investment and support mobilization to remove barriers and build enabling conditions.

f) **Nurture the development of institutional, social and policy capabilities through long-term programmatic activities**. This require dedicated financing for actions which are specifically focused on strengthening and building synergies across enabling conditions at the country level.

g) **Enable mission-oriented coordination and step up efforts across** intergovernmental organizations, governments, the private sector and civil society and continue to build partnerships at both global and national levels.

h) **Develop further work on integrating climate technology and governance frameworks at the national level, which is essential** to the delivery of successful climate technology projects in developing countries in the short, medium and long terms.

Part B

5.

Finance for Climate Technologies in Developing Countries

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5.1 INTRODUCTION

This chapter assesses finance for climate technologies, focusing on developing countries. Finance plays a critical role in addressing structural bottlenecks that inhibit the development and transfer of climate technology to developing countries due to challenges surrounding access to and the cost of finance and support for resourcing enabling environments.

The chapter considers two aspects of finance for climate technologies. First, it will consider the availability of public financial resources for climate technology development and transfer to support both enabling environments for climate technologies and public investment and procurement. Second, the chapter will look at the financial sector's role in mobilizing and deploying resources for enabling efficient investment in climate technologies and their use. Both aspects impact the efficiency of investment in and use of climate technologies. The chapter considers domestic and international finance to support climate technology development and transfer, as the domestic position provides critical context for the role and deployment of finance from international sources.

5.2 APPROACH

5.2.1 Public finance for technology development and transfer

The role of public finance for technology development and transfer has two primary dimensions. First, public finance provides the resources to expand the enabling environment for technology development and transfer. Second, public investment and procurement for public infrastructure invariably imply technology choices that are critical for transitioning towards climate-resilient pathways. This chapter analyses each of these two dimensions.

Public finance for enabling environments

Together with policy and regulatory measures, which do not fall within the scope of this chapter, public finance provides the resources that underpin the enabling environment for technology development and transfer. This chapter has adopted the following approach to assessing this aspect:

Domestic finance: Domestic public finance in support of the enabling environment for climate technology development and transfer can be estimated using government budget allocations for research and development (GBARD). While this indicator does not disaggregate climate from non-climate-related expenditure, GBARD that are directed towards core climate-related sectors (transport and infrastructure, agriculture, environment and energy) can serve as a proxy. This indicator is not available for the vast majority of developing countries, however. Only data on global research and development expenditure exists. GBARD is a subset of this, meaning that only very limited assessments can be made of domestic public support for the enabling environment for climate technologies.

International finance in support of the enabling environment for technology development and transfer is assessed using data on climate-related development finance from the Organisation for Economic Co-operation and Development [OECD] Creditor Reporting System.[9] A methodology was developed to estimate support to climate technologies (UNEP-CCC 2022). Within the identified activities, grant-based support was used as a broad estimate to measure activities that support the enabling environment for climate technologies, as transfers broadly targeting support for capacities, institutions, technical expertise and skills, and awareness-raising, all elements commonly taken to constitute an enabling environment.

Public investment and procurement

In addition to providing the resources that underpin the enabling environment for technology transfer and development, public finance plays a key role on climate technology through public investment and procurement. In particular, publicly financed or supported transport, energy and water infrastructure, public building and construction of facilities such as schools and hospitals, or public housing all include technology choices that are central to the use of climate technologies.

Domestic finance: Due to the limited disaggregated data on public investment in developing countries, analysis of public investment in or procurement of climate technologies is beyond the scope of this chapter. International Monetary Fund (IMF) data on investment and capital stock (IMF 2022) provides context for the scale of finance that reflects infrastructure investments, which are essential drivers for climate technology transfer and use. While this data offers quasi-universal country coverage for general government investment, it is not disaggregated by sector or technology, nor is it possible to identify the share of public investment accounted for by sustainable infrastructure.

9 Climate-related development finance reported through the OECD Creditor Reporting System and climate finance reported to the UNFCCC are different but have strong interlinkages and overlaps (OECD 2022). The linkages arise from the fact that public climate finance activities are, for the most part, also development finance activities, and therefore reported both to the UNFCCC and the OECD. Furthermore, the majority of Development Assistance Committee (DAC) members use their Rio markers data, reported to the OECD, as a starting point for their submission to the UNFCCC, making use of coefficients and other adjustments. At the same time, there are also differences in the data in relation to objective, methodology, granularity and detail, standardization, quality checking and country coverage.

Overall, a comprehensive database on public investment at the country level that captures or estimates the use of specific technologies across different sectors would be highly beneficial in helping to provide a robust evidence base for the future.[10]

International finance: The analysis of international support for public investment in and procurement of climate technologies is based on the methodology described above. Finance provided in the form of debt instruments was then used as an indicator to estimate public investment and procurement, as this kind of debt financing typically takes the form of project finance associated with public investment or procurement.

Overall, there are significant data limitations, particularly regarding information on domestic finance and support for climate technologies. These reflect the challenge posed by relative data scarcity in developing countries. While the availability of highly granular, activity-level data for development finance offers scope for more tailored, in-depth analysis, the basic data gaps relating to domestic finance are, overall, likely to represent amounts significantly greater than the financial support from international sources. This makes capturing a robust picture of overall finance for climate technologies inherently difficult.

5.3 PUBLIC FINANCE FOR ENABLING ENVIRONMENTS FOR CLIMATE TECHNOLOGY DEVELOPMENT AND TRANSFER

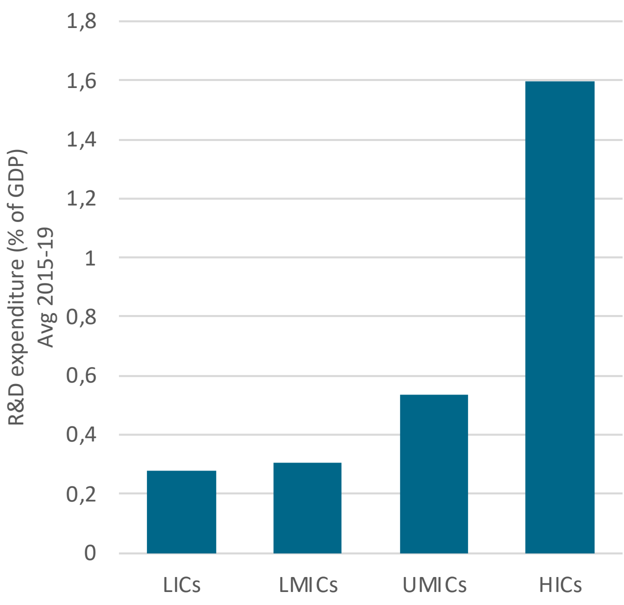
5.3.1 Domestic finance

The public sector plays a key role in establishing enabling environments for technology development and transfer. In addition to setting policy, which is instrumental in directing technological change (OECD 2018), government support for scientific and technical research is common in many countries and a critical resource underpinning the enabling environment for technology development and transfer. Support can take the form of both direct and indirect financial measures, ranging from grants allocated directly to researchers or institutions, to tax incentives or a government's own research institutions and facilities (Bernanke 2011).

The structural constraints faced by developing countries as they seek to adopt new technologies, including notably limited local technological capacities and know-how, are essentially the results of low public funding on research and development, limited infrastructure and institutional strength (United Nations 1990; United Nations Conference on Trade and Development [UNCTAD] 2003; UNCTAD 2003; UNCTAD 2003; UNCTAD 2004).

These constraints are clearly reflected in data relating to national expenditure on research and development. The share of gross domestic product (GDP) allocated to research and development as a whole is far lower in developing countries than in high-income countries (figure 8). Within developing countries, significant differences exist across income groups, with research and development as a share of GDP increasing with each income group. Overall, the share of GDP devoted to research and development expenditure is about three times higher in high-income countries than in upper-middle-income countries. This rises to between five and six times when high-income countries are compared with lower-middle-income or low-income countries.

Figure 8. Research and development expenditure as a share of GDP by income group



Notes: Left hand axis: Percentage. Research & Development expenditure (as a share of Gross Domestic Product) across income groups, over the period 2015–2019. Values are 2015–2019 averages.

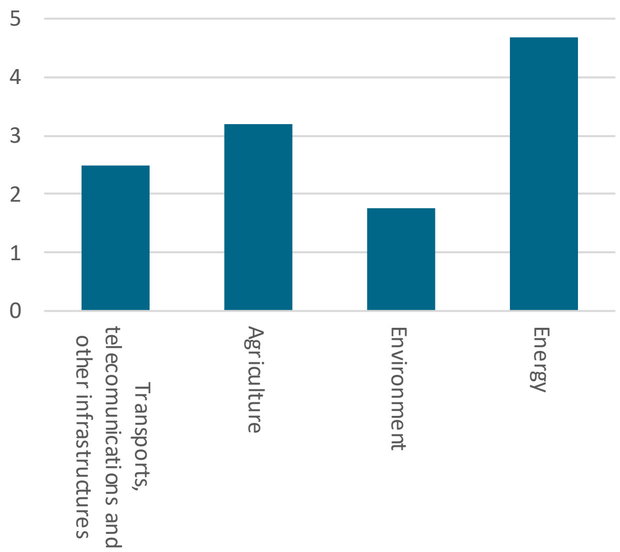
Source: Based on Figure 9.7 from IPCC (IPCC 2022d)

10 The OECD provides an overview of the challenges involved in identifying data and estimating infrastructure investments (OECD 2017). Detailed data is generated for selected countries covered under the IMF's Public Investment Management Assessments (IMF 2022). Several other sources provide more granular information with regard to sectors and geographies, however this mostly relates to infrastructure investment with private participation, such as the World Bank Private Participation in Infrastructure Project Database (World Bank 2022).

The difference becomes even starker when translating these shares into actual expenditure. In 2020, research and development expenditure averaged USD 814 per capita in high-income countries, which is more than 10 times as much as the USD 76 per capita spent in upper-middle-income countries. Average expenditure drops to USD 9 per capita for lower-middle-income countries, and USD 3 for low-income countries.

Moreover, GBARD is only a subset of total research and development expenditure, and data is currently available almost exclusively for OECD countries. Within this subset, support for key climate technology sectors accounts for only a small share. For the period 2015–2019, expenditure on core climate-related sectors (transport and infrastructure, agriculture, environment and energy) accounts for about 12 per cent of total GBARD in OECD countries (figure 9). While caution should be applied in drawing conclusions from this data, there is no reason to suggest that this share is likely to be fundamentally higher in developing countries.

Figure 9. Government research and development expenditure in key climate sectors – OECD economies

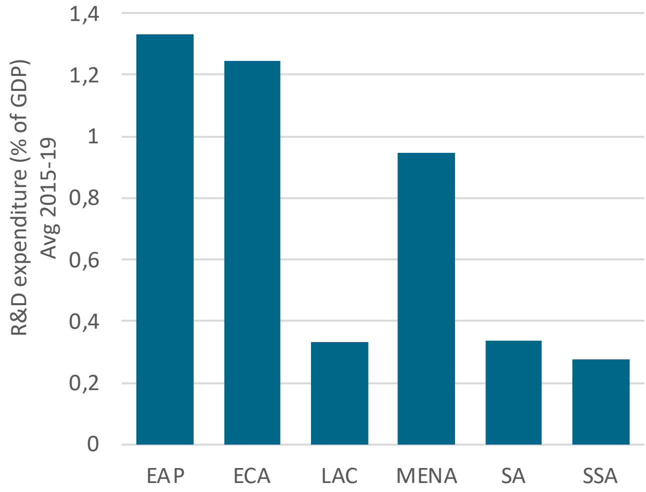


Notes: Left hand axis: Percentage. Sector-specific research and development expenditure (as a share of total government budget allocation to research and development) in different sectors, over the period 2015–2019. Values are 2015–2019 averages.

Source: Own analysis based on data from OECD (OECD 2022a)

Research and development expenditure fluctuates significantly by geographical region (figure 10). East Asia and the Pacific recorded the highest expenditure as a share of GDP, followed by Europe and Central Asia and then the Middle East and North Africa region. South Asia, Latin America and the Caribbean, and sub-Saharan Africa demonstrated considerably lower levels of expenditure.

Figure 10. Research and development expenditure (% of GDP)



Notes: Left hand axis: Percentage. Research and development expenditure (as a share of Gross Domestic Product) across regions, over the period 2015-2019. Values are 2015-2019 averages.

Source: Own analysis based on data from World Bank (World Bank 2022a)

Notwithstanding the significant limitations involved, the data clearly points towards the conclusion that direct government allocations to support an enabling environment for climate technologies are much lower in developing countries than in high-income countries. All indicators show a strong positive correlation between expenditure and rising income levels. This is consistent with the general concentration of technological development in a small number of countries, making technology transfer critical if the technological gaps between developed and developing countries are to be reduced (Maskus 2004)

Box 4 provides examples of public-private finance initiatives in Egypt.

Box 4. Case: Sustainable finance initiatives in Egypt

The Green for Growth Fund (GGF)[11] is the first specialized fund to advance energy efficiency (EE) and renewable energy (RE) in Southeast Europe, including Turkey, as well as in the nearby European Eastern Neighborhood region and in the Middle East and North Africa (MENA). Initiated by the European Investment Bank and KfW Development Bank, the GGF is an innovative public-private partnership established in 2009 to promote energy efficiency and reduce CO2 emissions in the target regions.

On the one hand, the GGF provides credit lines to local financial institutions to finance different types of EE/RE measures (for buildings, agriculture, transport etc.). On the other hand, GGF can also invest directly in EE/RE projects. The GGF invests in projects which reduce energy consumption and/or CO2 emissions by a minimum of 20% and this is what GGF's investments seek to achieve.

The GGF's investment activities are complemented by the Technical Assistance Facility (TAF), which helps the fund achieve its objectives while ensuring a long-term impact. Further, the GGF TAF engages a dedicated Energy Consultant for each of its partner financial institutions to assess and verify the eligibility of certain sub-loans. These evaluations are applied to complex projects that are categorized as non-standardized and not included in the list of standardized projects that has been established.

In Egypt, GGF has established a partnership with Banque du Caire (BdC) by providing a credit line of USD 10 million to finance EE and RE projects. Other public finance initiatives in Egypt for enabling environments, includes:

- **Central Bank of Egypt initiative for MSMEs offers attractive loans at 5%, 7%, and 12%.**
- **Green Economy Finance Facility (USD 5 million ceiling, 10-15% grant) supported by the Southern and Eastern Mediterranean (SEMED) Multi-Donor Account (MDA).**
- **Green for Growth Fund (GGF) with Banque du Caire (BdC) by providing USD 10 million as a credit line to finance EE and RE projects. The goal of the project is to achieve a minimum 20% reduction in energy consumption and/or a minimum 20% reduction in CO2 emissions.**
- **Egyptian Pollution Abatement Programme - EPAP (EUR 15 million ceiling, 10-20% grant) supported by several development partners.**
- **Environmental Compliance Office - Federation of the Egyptian Industries; ECO-FEI (EGP 7 million ceiling, 2.5% interest rate).**

11 www.ggf.lu

5.3.2 International finance

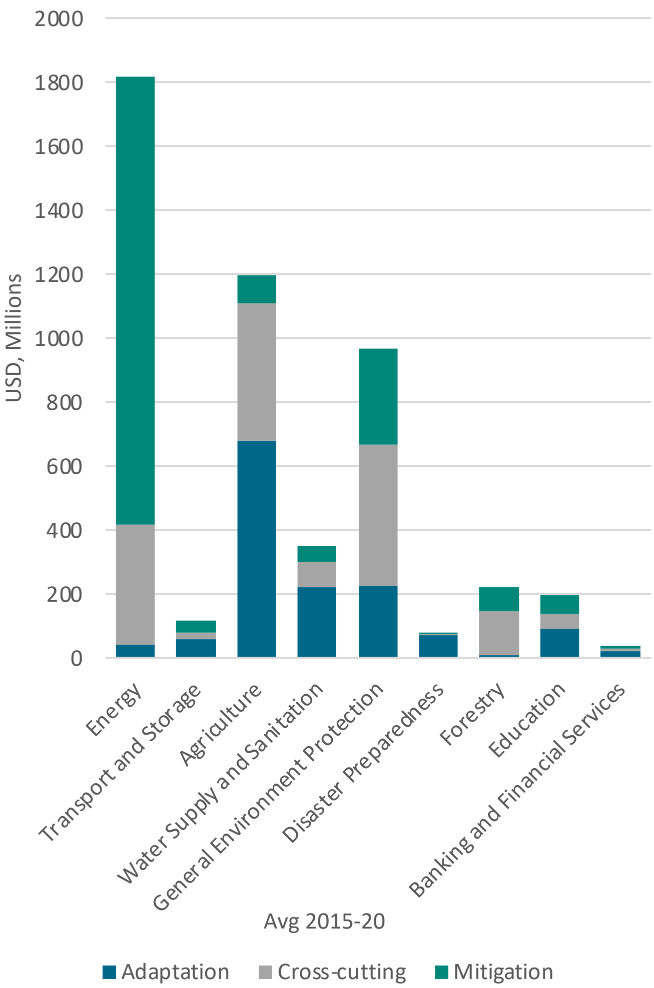
An analysis of international support to help create enabling environments for climate technology development and transfer shows that development finance plays a key role in complementing scarce domestic resources, especially for low-income countries.

In 2015–2020, development finance in the form of grants provided an average of USD 5.9 billion per year to support enabling environments for climate technologies. This was split relatively evenly between support for adaptation (USD 1.8 billion), mitigation (USD 2.2 billion) and cross-cutting activities (USD 1.9 billion). When broken down by sector, energy accounted for the largest share of this finance, with significant volumes also directed towards agriculture and general environmental protection (figure 11).

By income level, low-income countries receive the largest share of support related to enabling environments (figure12). Support for lower-middle-income countries was only slight lower, but dropped substantially for upper-middle-income countries. Overall, this is a reversal of the picture emerging from the domestic expenditure figures.

In terms of regional distribution, sub-Saharan Africa receives by far the highest levels of support (USD 1.42 billion), which is relatively evenly split between adaptation activities (USD 0.46 billion), mitigation activities (USD 0.49 billion) and cross-cutting activities (USD 0.47 billion). The remaining climate-related development finance for technology development and transfer channelled through grants is relatively evenly split between the other regions, and between adaptation, mitigation and cross-cutting activities.

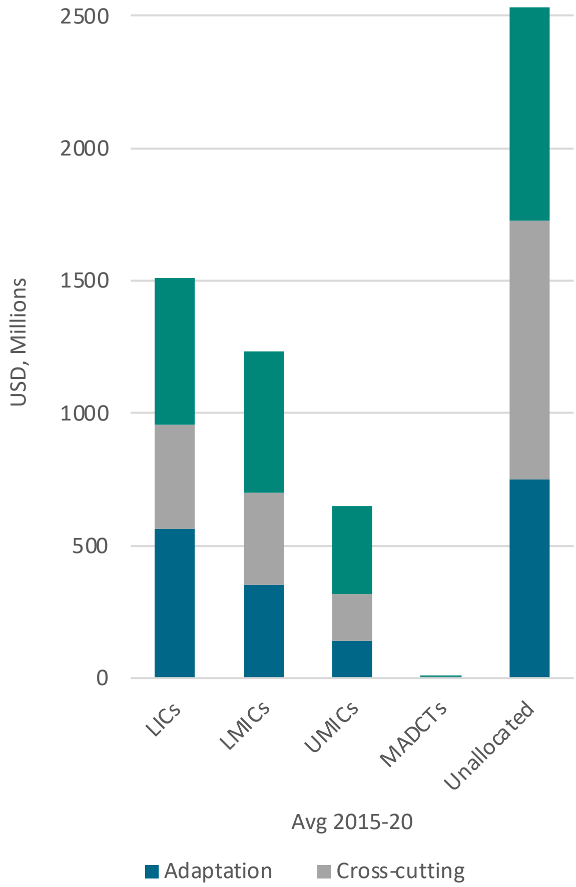
Figure 11. Development finance for climate-technology enabling environment (grants) – sector distribution



Notes: Left hand axis: USD millions. Development finance for climate-technology enabling environment (grants) to different sectors, over the period 2015-2020. Values are 2015-2020 averages. Cross-cutting includes activities that are both marked as mitigation- and adaptation-relevant.

Source: Own analysis based on data from OECD (OECD 2022b)

Figure 12. Development finance for climate-technology enabling environment (grants) – regional and income level distribution



Notes: Left hand axis: USD millions. Development finance for climate-technology enabling environment (grants) to different income groups, over the period 2015-2020. Values are 2015-2020 averages. Cross-cutting includes activities that are both marked as mitigation- and adaptation-relevant.

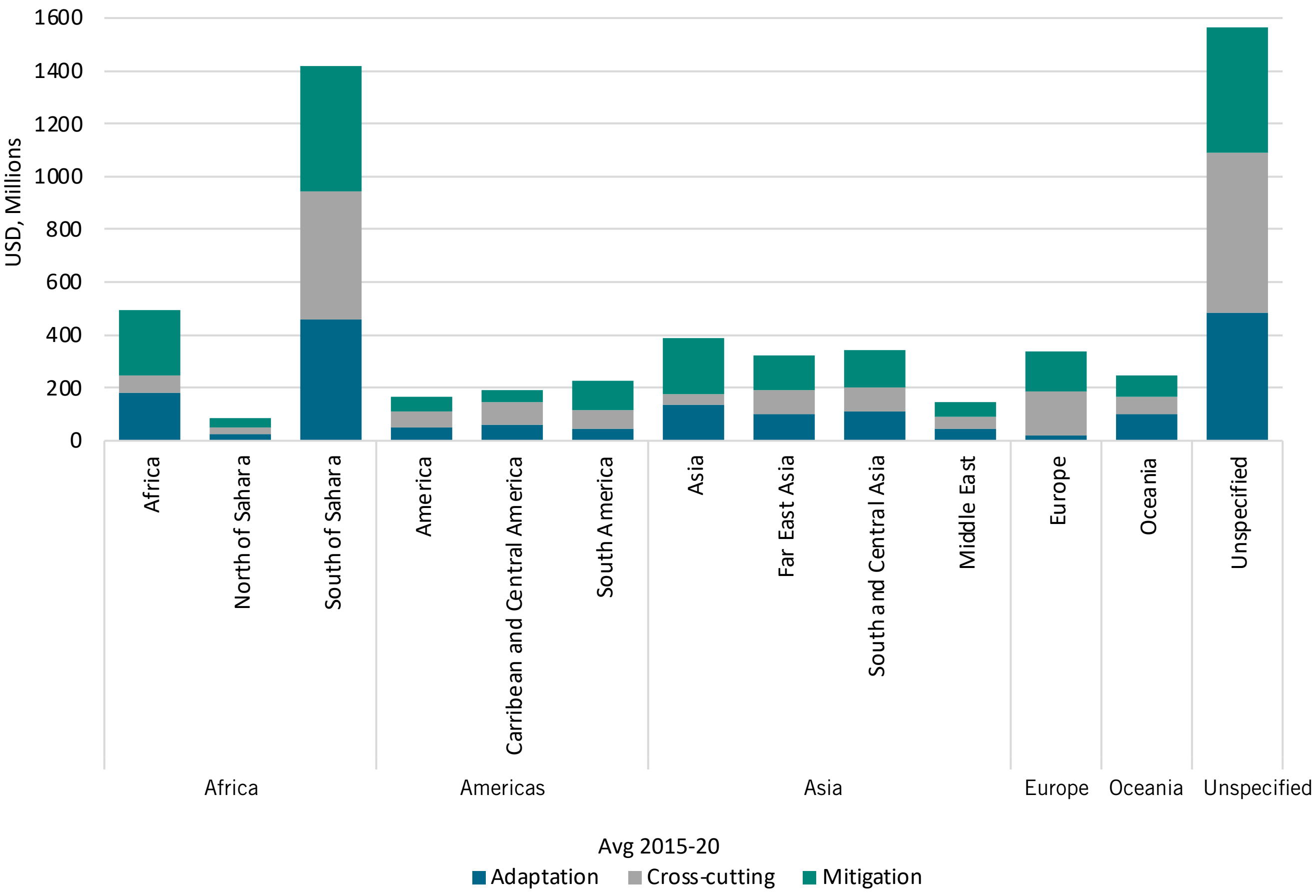
Source: Own analysis based on data from OECD (OECD 2022b)

It is also important to note the high share of finance that is unallocated by income group (USD 2.5 billion) or unspecified by region (USD 1.56 billion). While further analysis is required to draw conclusions with confidence, this may indicate that a substantial share of support is being directed towards cross-country activities or broader international initiatives that support climate technology development and transfer.

By comparing the results obtained from analysing domestic expenditure and from analysing the support provided through development finance, it is possible to estimate the contribution made by international support. In the case of sub-Saharan Africa, for example, development finance to support enabling environments for climate technology development and transfer amounted to an average of USD 1.4 billion per year, corresponding to 0.073 per cent of the region's gross national income (GNI) in 2021. With total research and development expenditure, both private and public, standing at 0.2 per cent of GDP in the region, and across all sectors, the support provided through development finance constitutes a very significant share, equivalent to over a third of total expenditure. The share relative to government allocations for climate-related purposes is likely substantially higher.

The substantial contribution made by international financial support relative to domestic resources in creating enabling environments for climate technology development and transfer, particularly in low-income countries, heightens the importance of coordinating this support and ensuring that it is aligned with domestic priorities and plans. Given that developing countries are prioritizing mature technologies for their climate action, it is particularly important to build broader institutional and human capacity to support enabling environments for technology development and transfer over the long term. This will help to overcome current basic constraints for enhanced action (UNEP-CCC 2022).

Figure 13. Development finance for climate-technology enabling environment (grants) – sector distribution



Notes: Left hand axis: USD millions. Development finance for climate-technology enabling environment (grants) to different regions, over the period 2015-2020. Values are 2015-2020 averages. Cross-cutting includes activities that are both marked as mitigation- and adaptation-relevant.

Source: Own analysis based on data from OECD (OECD 2022b)

5.4 PUBLIC INVESTMENT IN AND PROCUREMENT OF CLIMATE TECHNOLOGIES

5.4.1 Domestic finance

Investment in public infrastructure is a core function of government, and essential for long-term growth. This kind of expenditure invariably implies technology choices that are critical in the transition to climate-resilient, net-zero economies.

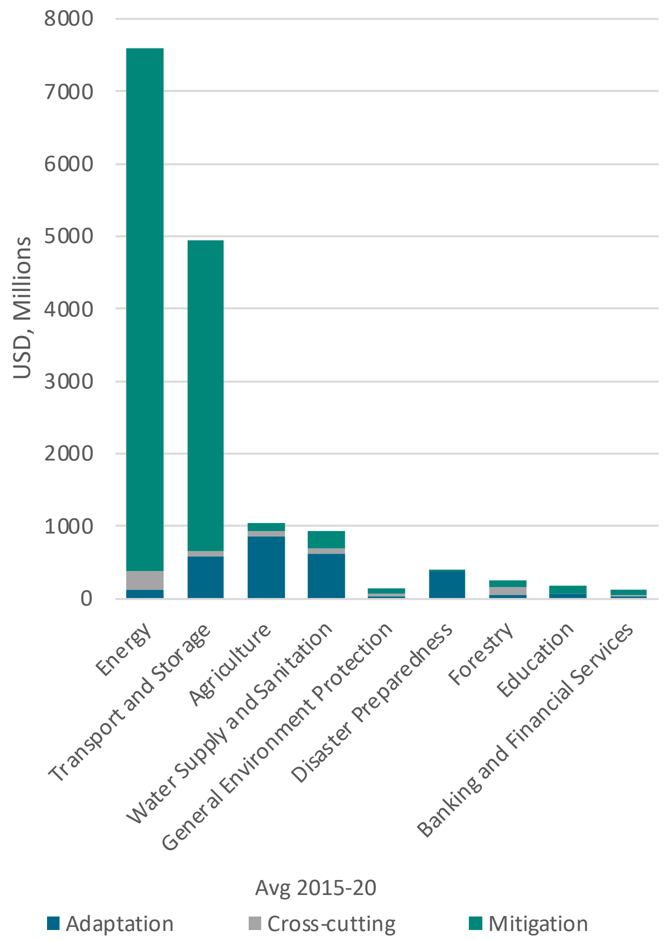
Unlike other indicators, public capital stock levels vary widely within income groups and show no correlation with income level. With the exception of individual outliers, these levels range between 30 per cent and 160 per cent of GDP (IMF 2022). Despite this variation, a comparison with the capital stock of public-private partnerships (PPPs) is indicative for its historic significance. While mobilizing finance and investment through private participation in infrastructure is broadly understood to play an important role in meeting overall infrastructure investment needs, the capital stock of PPPs currently ranges, with very few exceptions, between close to zero and 6 per cent of GDP.

5.4.2 International finance

The provision of finance for public investment by developing countries at affordable terms is one of the traditional core functions of development finance. The operating model of multilateral development banks, in particular, is based on their ability to raise funds cheaply from the financial markets and to pass these funds on to developing countries at favourable terms and tenors these countries are not able to obtain. The funds are typically earmarked as project financing for public investment in economic infrastructure.

This traditional focus is also reflected in the way that public investment supported through climate-related development finance is distributed by sector. The bulk of finance provided through these debt-based instruments from 2015 to 2020 went to energy (USD 7.6 billion), followed by transport and storage (USD 4.9 billion) (figure 14). Together, these two sectors accounted for about 80 per cent of the total USD 16.1 billion. In addition, climate-related development finance channelled through debt was predominantly targeted at mitigation.

Figure 14. Development finance for climate technology procurements and investments (debt instruments) - sector distribution



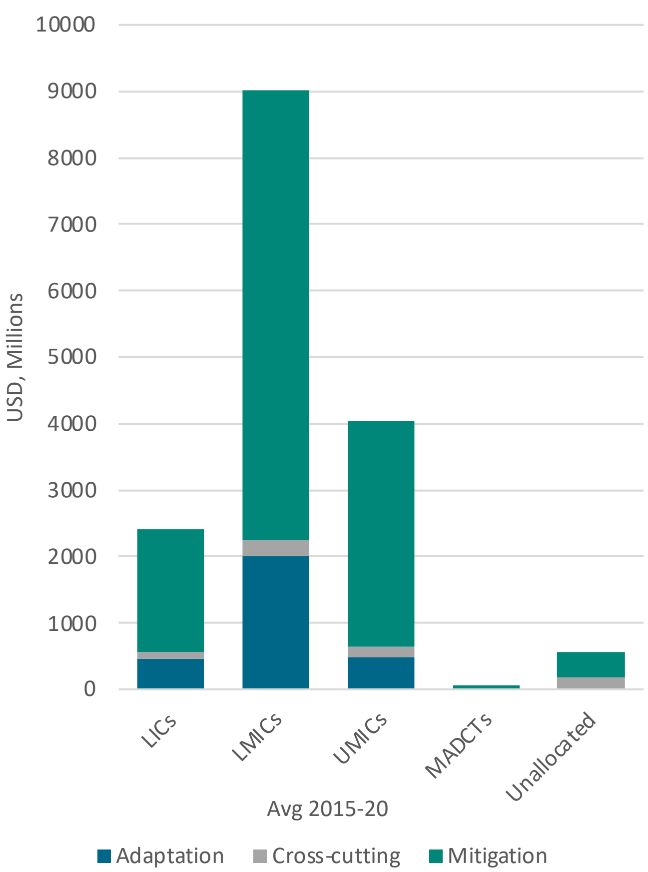
Notes: Left hand axis: USD millions. Development finance for climate-te nology procurements and investments (debt instruments) to different sectors, over the period 2015-2020. Values are 2015-2020 averages. Cross-cutting includes activities that are both marked as mitigation- and adaptation-relevant.

Source: Own analysis based on data from OECD (OECD 2022b)

Figure 15 provides an overview of how climate-related velopment finance for technology transfers (debt inst ments) was split across income groups. Between 2015 2020, low-middle-income countries were the most targe income group by far (USD 9 billion). Finance to upper-m dle-income countries accounted for only about a third of t amount, and low-income countries received the least mate-related development finance. In terms of regional tribution, Asia, East Asia, and South and Central Asia have been the primary recipients for climate-related development finance channelled through debt instruments (USD 10.1 billion), while Africa, North Africa and sub-Saharan Africa lag behind (USD 2.5 billion), reversing the picture for support for enabling environments. The very small share that is unallocated by income group or region reflects the fact that the investments associated with the financing typically relate to tangible assets in a specific geography or jurisdiction.

Overall, the allocation pattern is very different to the pattern of support for enabling environments, pointing both to the constraints surrounding public finance and absorptive capacity in low-income countries, and to an increasingly diverse range of financing options for upper-middle-income countries, reducing the relative significance of international public finance in their overall financing mix.

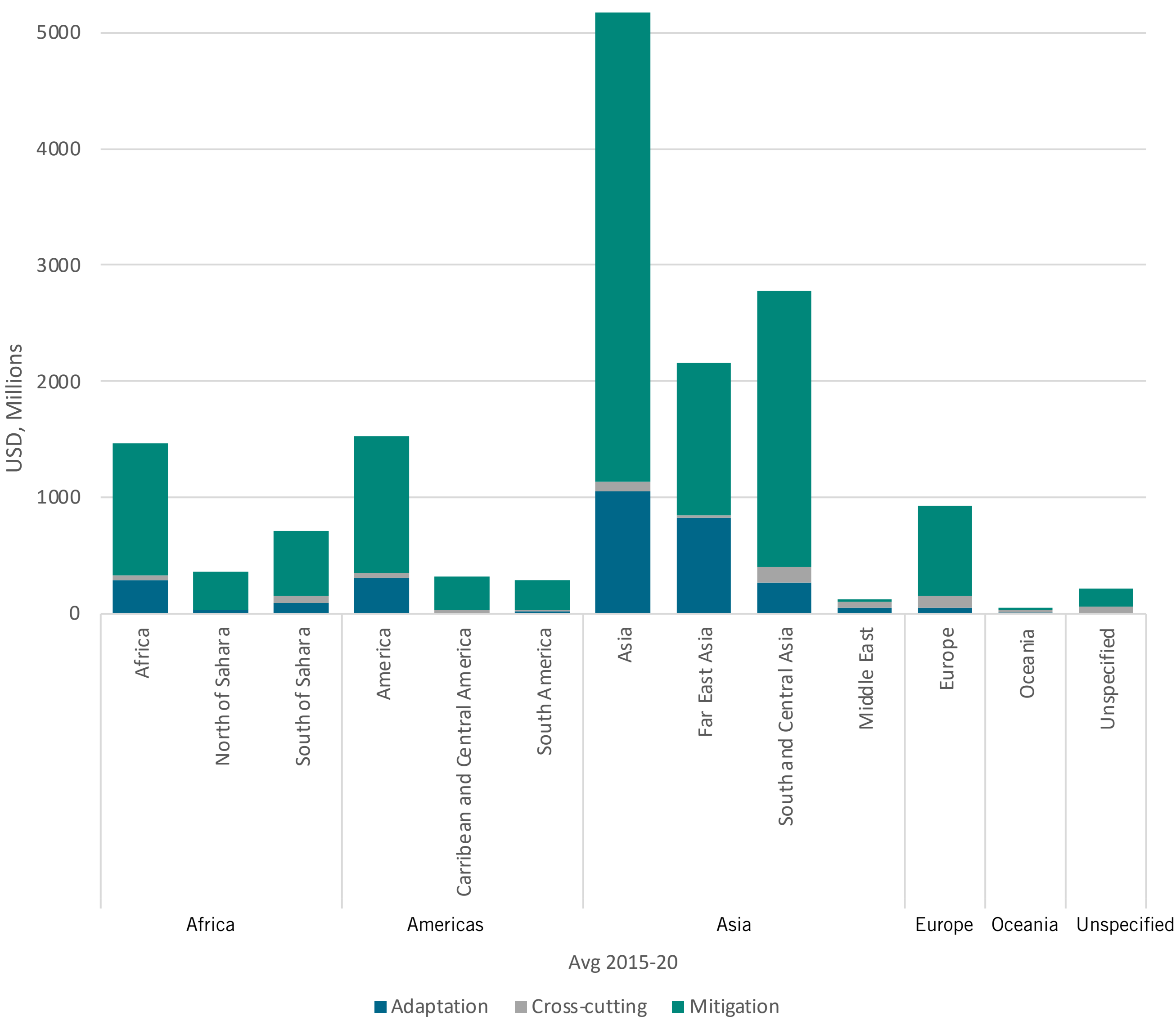
Figure 15. Development finance for climate technology procurements and investments (debt instruments) – distribution by region and income level



Notes: Left hand axis: USD millions. Development finance for climate-technology procurements and investments (debt instruments) to different income groups, over the period 2015-2020. Values are 2015-2020 averages. Cross-cutting includes activities that are both marked as mitigation- and adaptation-relevant.

Source: Own analysis based on data from OECD (OECD 2022b)

Figure 16. Climate-related development finance for technology transfers channelled through debt instruments



Notes: Left hand axis: USD millions. Development finance for climate-technology procurements and investments (debt instruments) to different regions, over the period 2015–2020. Values are 2015-2020 averages. Cross-cutting includes activities that are both marked as mitigation- and adaptation-relevant.

Source: Own analysis based on data from OECD (OECD 2022b)

Despite the substantial amount of finance provided for climate technology investments, this pales into insignificance when considering the overall need for the deployment of climate technologies in developing countries. Analysis in 2016 estimated that only around 6–7 per cent of infrastructure financing in developing countries was provided by development finance, although low-income countries relied much more on support from development partners than middle-income countries, due to their weaker capacity to mobilize domestic and external private finance (Miyamoto & Chiofalo 2016).

Given that development finance traditionally accounts for only a small share of investment in the key climate technology sectors, and one that is decreasing rapidly as income levels rise, the bulk of financing will have to be generated from domestic financial systems and their enhanced access to global financial markets and capital pools.

This makes overall financial development and increased financial depth essential for developing countries' abilities to provide financing solutions for the infrastructure investments and associated climate technologies that are required to achieve Paris-aligned sustainable development. In the same vein, the need to unlock finance at different magnitudes compared with historical volumes has led to an increasing focus on more catalytic use of scarce development finance resources, and an evolution of the operating models used by development banks and finance institutions (OECD, UNEP, & WB 2018)

5.5 FINANCIAL SECTOR CAPACITY TO SUPPORT CLIMATE TECHNOLOGY DEVELOPMENT AND TRANSFER

5.5.1 Domestic action

Domestic financial sectors will have to play a key role in enabling the large-scale development and transfer of climate technologies in developing countries. The role of financial markets and institutions ranges from the sovereign cost of borrowing, which is central to a government's ability to issue and manage debt for public investment, to financial products for specific technologies or uses that are a key condition for market creation, to the availability of financial services as a fundamental input for private firms and their productivity (Arnold, Matoo & Narciso 2006).

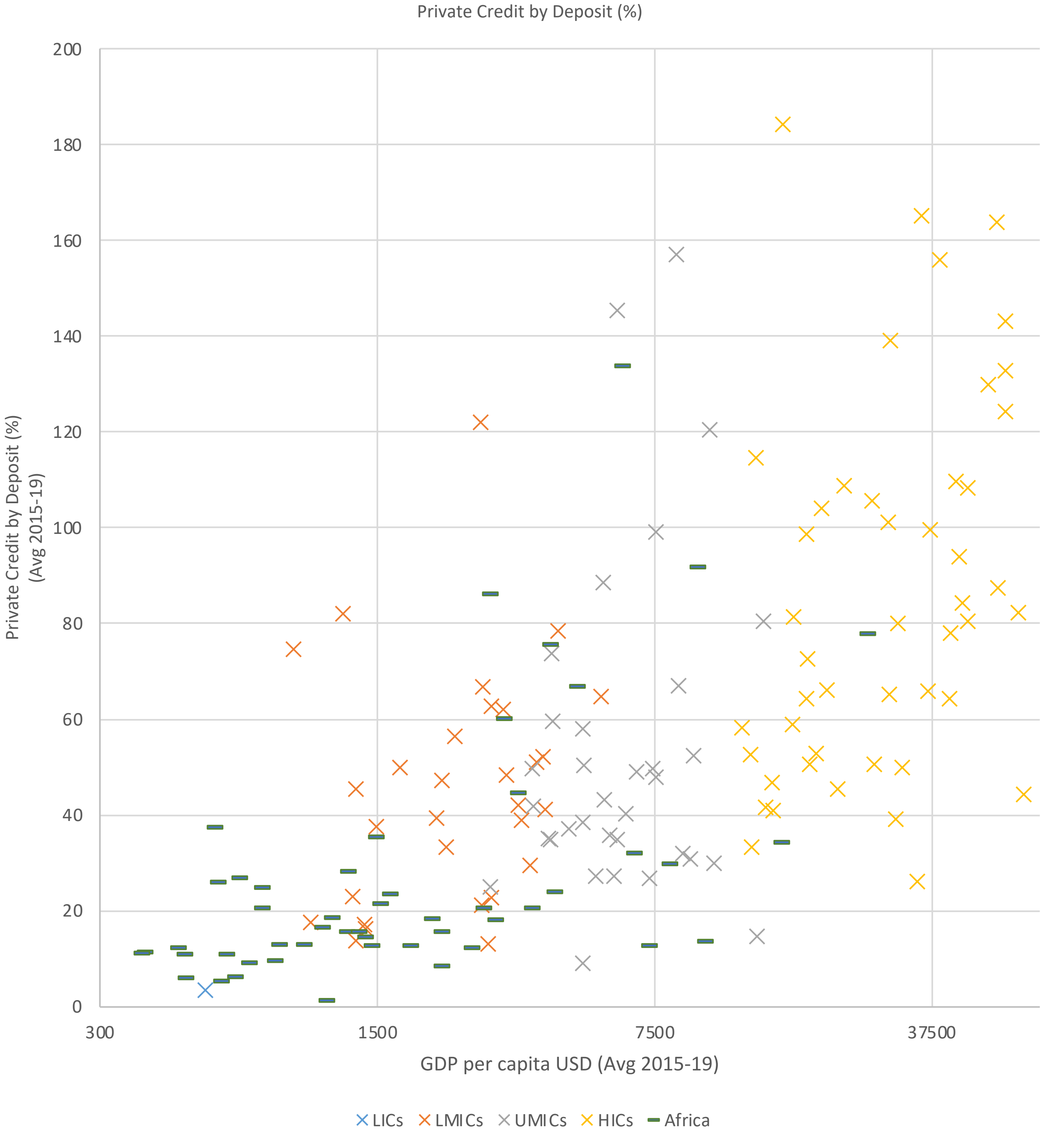
Financial development entails improvements in the quality of five key functions: (i) producing and processing information about possible investment and allocating capital based on these assessments; (ii) monitoring individuals and firms, and exerting corporate governance after allocating capital; (iii) facilitating the trading, diversification and management of risk; (iv) mobilizing and pooling savings; and (v) easing the exchange of goods, services and financial instruments (Levine 2001).

Several initiatives are helping to ensure that climate change dimensions, including an explicit focus on technology dimensions, are appropriately reflected in these functions. These include the Network of Central Banks and Supervisors for Greening the Financial System and the Financial Stability Board's Task Force on Climate-related Financial Disclosures. The increasing participation by developing countries in these initiatives reflects the countries' demand to share in peer learning and dissemination of best practices to manage risks and mobilize capital for investments that are aligned with climate objectives.

At the same time, basic financial sector development is a necessity for the integration of climate dimensions, and a precondition for effective mobilization and allocation of finance at a scale that can support the development and transfer of climate technologies. An assessment of two basic dimensions of financial development, access to finance and financial sector depth, shows a clear, positive correlation between income levels and financial development indicators, despite some heterogeneity (Figure 17, 18 and 19). This corroborates empirical studies which have identified particular challenges with regard to access to finance, especially in the sub-Saharan Africa region (Cull and Demirgüç-Kunt 2013; Kendall 2010).

United Nations headquarters in New York City, USA
Sergii Figurnyi, Shutterstock

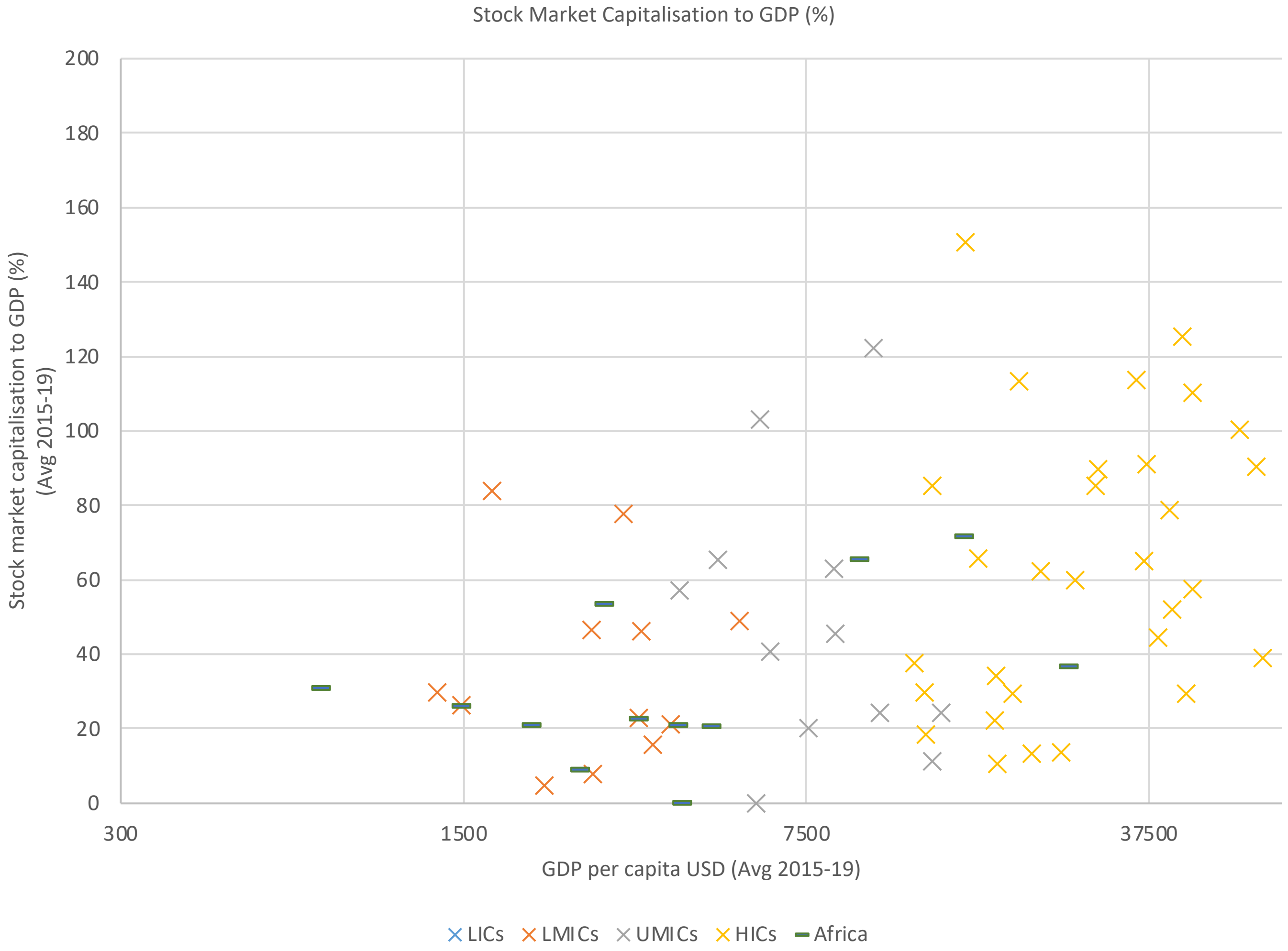
Figure 17. Financial sector depth – Financial institutions



Notes: Left hand axis: Percentages. Bottom axis: USD $. The depth of financial institutions is proxied by the share of private credit by deposit plotted against logged GDP per capita, over the period 2015-2019. Values are 2015-2019 averages.

Source: Own analysis based on data from World Bank (World Bank 2022b)

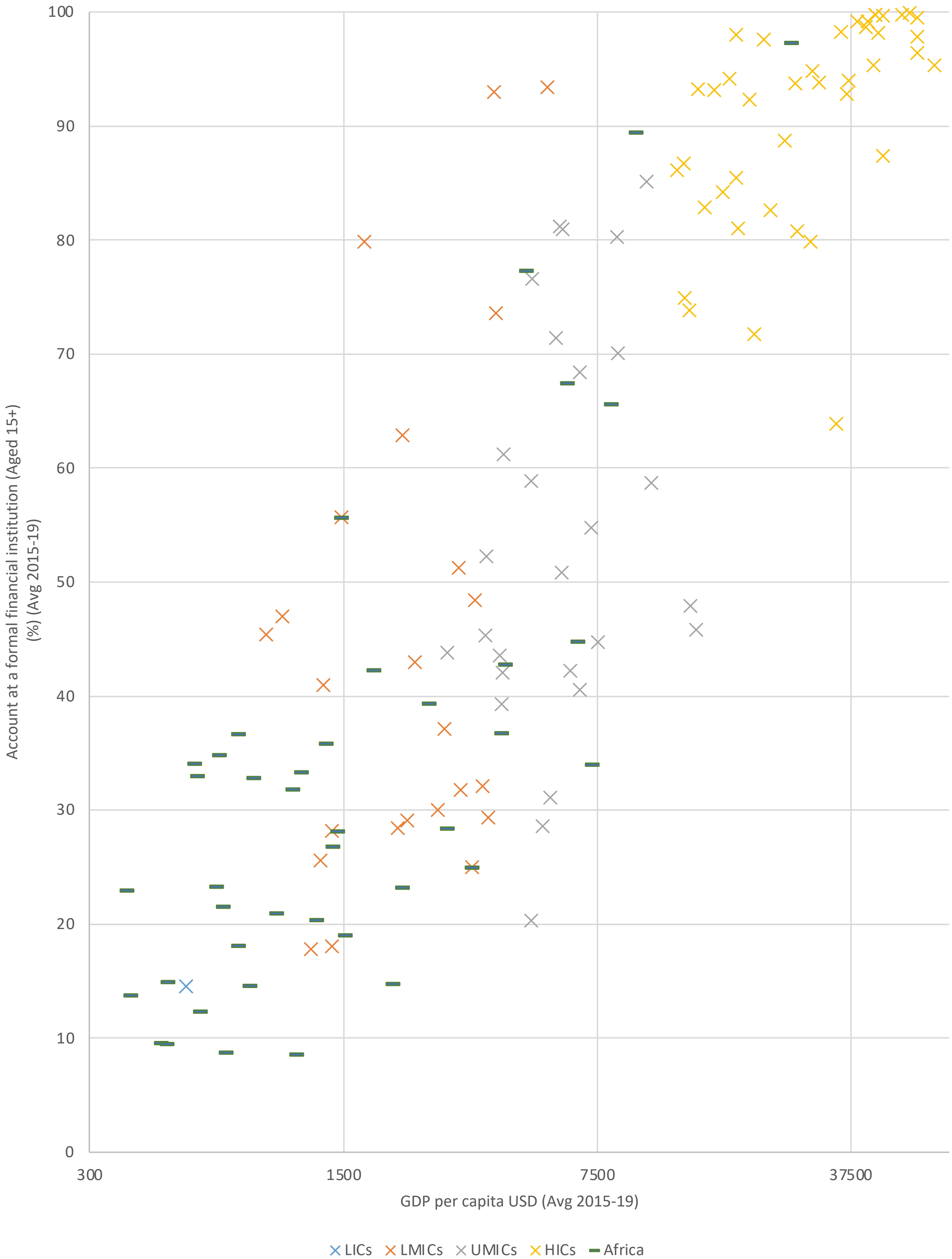
Figure 18. Financial sector depth – Financial institutions



Notes: Left hand axis: Percentages. Bottom axis: USD $. The depth of financial markets is proxied by stock market capitalization as a share of GDP plotted against logged GDP per capita, over the period 2015-2019. Values are 2015-2019 averages.

Source: Own analysis based on data from World Bank (World Bank 2022b)

Figure 19. Access to financial institutions and services



Notes: Left hand axis: Percentages. Bottom axis: USD $. Access to financial institutions and services is proxied by a country's accounts at a formal financial institution (as a share of people aged 15 or more) plotted against logged GDP per capita, over the period 2015-2019. Values are 2015-2019 averages.

Source: Own analysis based on data from World Bank (World Bank 2022b)

Improving financial sector depth is particularly important for climate technologies, in that it increases investment efficiency and reduces the cost of finance. Limited financial sector depth often significantly increases the cost of capital for renewable energy in developing countries compared with high-income countries (Steffen 2020). The lack of access to financial institutions and services in developing countries hampers asset accumulation, efficient risk management and the development of entrepreneurial opportunities (A. Demirgüç-Kunt 2008; Beck 2014). All of these factors are key for enabling investment in and use of climate technologies. The importance of access to finance applies also, and in particular, to mature climate technologies, which make up a high proportion of the technologies identified by developing countries in their technology needs assessments (UNEP CCC 2022).

Overall, financial development plays a key role in developing countries, helping to mobilize finance at scale and from diversified sources, which they require for climate investment. While financial development is a gradual and long-term process, integrating emerging good practice for greening the financial sector will play an important role in ensuring the economic efficiency of investments, and thereby optimizing the mobilization and allocation of finance for technology development and transfer.

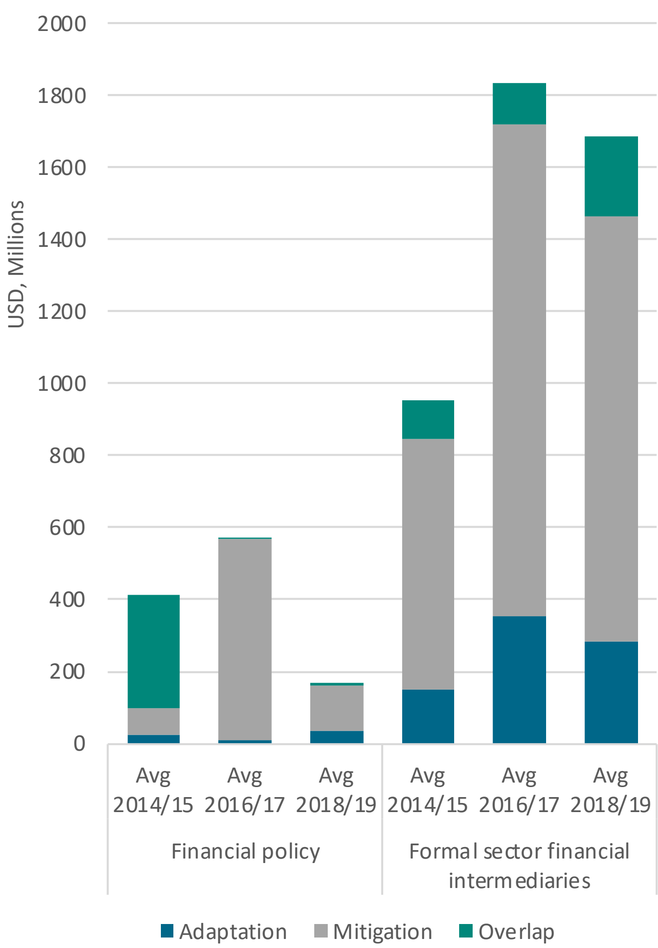
5.5.2 International action

The need for a step change in financing for climate investment to achieve climate-resilient, net-zero pathways through technology development and transfer has led to development finance increasingly focusing on mobilization. Targeted development finance interventions that unlock financing can help accelerate financial development, and the financial sector plays a central role in this regard. By bridging viability gaps for individual transactions that are the result of market failure, such blended finance interventions can help unlock commercial finance and contribute to creating markets for technology development and transfer.

In 2020, following increases in previous years, banking and financial services emerged as the sector that generated the highest share of private finance mobilized by development finance overall, at USD 17.7 billion (Bartz-Zuccala, Taskin, Hos, Sangaré and Horrocks 2022). Within climate finance, private finance mobilized for banking and financial services accounted for an average of just USD 1.3 billion, or 9 per cent of the total private finance mobilized for the period 2016–2020, lower than mobilization in the energy, industry, and mining and construction sectors (OECD 2022). The distribution by region and income level – with Asia and upper-middle-income countries receiving the highest concentration of private finance mobilized for climate – points to the mobilization of private finance being skewed towards higher income groups, and regions where investment performance is already strong.

Mobilizing private finance to and through the financial sector is often supported with the aim of unlocking follow-on financing from private sources, and of promoting market creation, often in geographical areas. Direct support for financial sector development can be deployed to strengthen the underpinnings and basic functioning of the financial sector, including by targeting specific climate objectives, deployed towards either financial policy or formal sector financial intermediaries. (Figure 20).

Figure 20. Climate-related development finance for financial sector development 2-year averages, commitments in USD 2019 prices



Notes: Preliminary data. Left hand axis: USD million. Overlap includes activities that are both marked as mitigation and adaptation-relevant.

Source: Own analysis based on data from OECD (OECD 2022b)

Formal sector financial intermediaries, such as banks and insurance companies, received the highest volumes of climate-related support in absolute terms from 2014 to 2019 (an average of USD 1.5billion) (OECD, forthcoming). To promote the uptake of specific climate technologies, multilateral development banks commonly provide a credit line to a local bank that has the local presence required for retail distribution to clients, alongside technical assistance relating to the technology and a tailored financial structure for its commercialization. This support is key, given that financial institutions need internal know-how and experience to undertake due diligence and adequately price risk, a capacity that is often lacking in the case of technologies for which these institutions have not traditionally offered financing products (OECD 2022).

Support for financial policy was relatively lower, averaging USD 384 million over the period 2014–2019. Rather than addressing specific financing products for climate technologies, policy dimensions relate to the broader integration of climate change dimensions into financial systems, giving them a key role in the overall efficient pricing of climate technologies within an economy. By definition, interventions to support financial policy would typically not involve instruments to disburse and channel large volumes of finance, such as credit lines. Instead, support typically takes the form of targeted provision of policy and regulatory support, as well as the associated expertise and capacities (OECD, forthcoming).

5.6 CONCLUSION

Finance has a key role to play in relation to the structural constraints that inhibit technology development and transfer in general, notably for resourcing the enabling environment, and with regard to access to and the cost of finance. These same factors are often aggravated in the context of technologies, from technologies procured through public infrastructure investment, to those used by smallholder producers or private consumers. Specific factors in this regard include the need to build capacity – to expand the enabling environment – for new technologies in developing countries, as well as the high capital intensity of many climate technologies, which magnify the constraints resulting from limited access to and the high cost of finance.

The tighter the constraints of public finances in developing countries, the more important the role of development finance. In particular, in countries with low income levels, donor financing can account for a significant share of total support for resourcing the enabling environment for technology development and transfer.

The large-scale investment required to achieve sustainable development based on climate-resilient, net-zero pathways will require the mobilization of finance from private markets, while direct financing of investment projects that deploy climate technologies will remain an important dimension of international support. To contribute most effectively towards this mobilization, in light of its basic limitations of scale, development finance needs to be deployed in a catalytic fashion. A financial sector that provides access to finance and available financial services can play a key role in addressing the constraints identified by developing countries relating to the cost and affordability of technology – from large-scale infrastructure to individual consumers and micro-entrepreneurs.

Overall, the availability of financial services for investment is a basic factor for the viability of technology development and transfer. This makes financial services a key factor in the overall enabling environment for climate technology transfer and investment. Both general financial development and targeted interventions focusing on green finance can help increase financing for climate technologies and associated investment. Finally, financial interventions are most effective if they are deployed not only to compensate for viability gaps in individual transactions, but also to help resolve market failure and contribute, beyond their direct mobilization, to creating markets for climate technology development and transfer.

Part C

6.

Climate technology progress in the African context: A snapshot

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6.1 INTRODUCTION

This chapter continues and builds on the previous chapters of the report. It provides a snapshot of the macro trends in climate technology progress, in terms of technology development and transfer in various parts of Africa, with a particular focus on the energy, agriculture and water sectors. It also presents case studies for each of these sectors. It then reflects upon recent changes in the climate technology landscape, drawing on the feasibility dimensions and enabling elements outlined in Chapters 3, 4 and 5 to gain a better understanding of the factors underlying (or hindering, as the case might be) progress for the selected climate technologies.

In line with the nature of this scoping report, this chapter merely scratches the surface in its investigation of climate technology progress, which is highly variegated, complex and non-linear. The intention is to provide a **high-level snapshot** of the current state of play and some **initial reflections** on progress in the African context.

6.2 THE EVOLVING CLIMATE TECHNOLOGY LANDSCAPE IN AFRICA

This section provides an overview (in terms of technologies, scale of diffusion and spatial distribution) of the macro trends underlying climate technologies **in the energy, water and agriculture sectors in Africa**. In addition, the section briefly highlights the trends and developments in the innovation and technology hub space. This is followed by three case studies that provide examples of specific climate technology in each sector, which will be reflected upon in Section 3.

6.2.1 Energy sector

Technologies such as wind power, solar photovoltaic (PV), geothermal and bioenergy are being widely introduced in Africa.

- Over the last decade, the deployment of renewable energy (wind and solar) across the African continent has increased, from 1.1 GW in 2010 to 18.7 GW in 2021. See figure 12 (IRENA 2022).

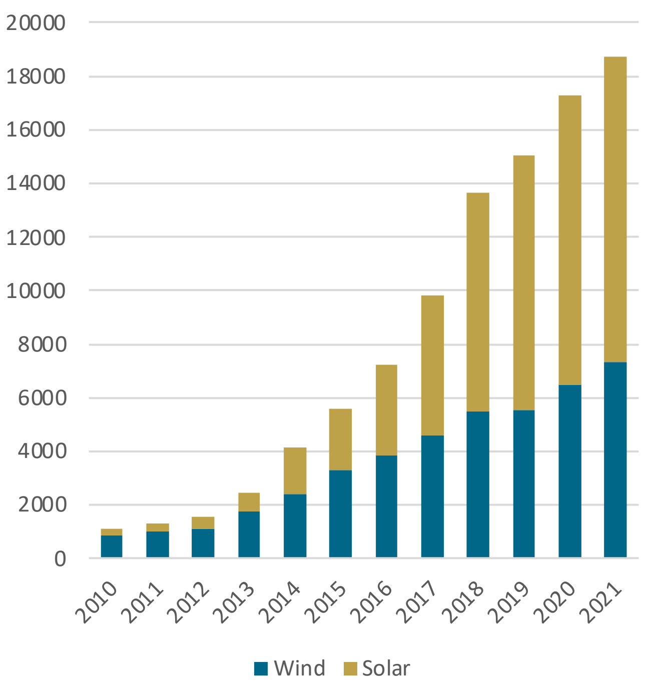
- Solar energy is the fastest growing renewable energy source in Africa. Total solar additions over the past decade have amounted to 10.4 GW (IRENA 2022). Kenya, Ghana and Nigeria all have a high number of solar PV home systems, while countries with utility-scale systems include South Africa, Kenya, Zambia, Senegal and Namibia. Solar mini-grid capacity totalled 54 MW in sub-Saharan Africa. Concentrated solar power is gaining ground in South Africa and Namibia, with an anticipated cumulative total of 700 MW by 2023 (Ren21 2022).

- Wind power facilities are mainly concentrated in South Africa, Morocco, Egypt, Kenya, Ethiopia and Tunisia, which cumulatively account for over 95 per cent of Africa's total wind power generation.

- Geothermal projects are in operation or planned in Kenya, Ethiopia, Djibouti, Uganda and Tanzania.

- Some countries are transitioning from traditional bioenergy use towards clean cooking solutions including LPG, cleaner biomass (briquettes and pellets) and renewable energy-based (electric pressure cookers) solutions. Kenya, Ethiopia and Senegal are leading the way in terms of adopting these solutions (Ren21 2022).

Figure 21. Installed RE capacity for wind and solar in Africa 2010 -2021



Source: IRENA Renewable Energy Regional Trends 2022 (IRENA 2022)

6.2.2 Agriculture sector

Technology development and transfer in the agriculture sector in Africa is mainly occurring in the areas of crop diversification and climate-resilient crop varieties, irrigation systems (including drip, sprinkler and solar-powered systems), and information and communication systems (including mobile apps, sensors and drones) (Afopke 2022).

- New, early-maturing, resilient crop varieties, including drought-, flood-, heat-, and pest-tolerant varieties, have been introduced across African countries. For example, over 200 improved, climate-resilient maize varieties have been introduced across 13 countries in sub-Saharan Africa (CGIAR 2021).
- Low-cost solar irrigation systems have been introduced in seven countries in sub-Saharan Africa: Burkina Faso, Gambia, Mali, Mauritania, Niger, Nigeria and Senegal (International Center for Biosaline Agriculture [ICBA] 2017).
- Information technologies include mobile and web apps providing advice to farmers, weather forecasts, market information and financial tips (Ekekwe 2017); sensors to monitor soil (for example, the IBM project in Kenya); and drones to monitor farms, and assess vegetation health and stressed zones (in South Africa, for example); and farming insurance schemes taking advantage of the Internet of things to predict yield in Uganda and Mali (CA Global 2017).
- Several climate-smart agriculture initiatives (Hou et al. 2016) are under way including improved coffee farming practices in Uganda, improved irrigation techniques and productivity in Tanzania, improved soil health in Ethiopia, sustainable agriculture practices and livestock productivity in Zambia and drought-tolerant crops in Morocco (World Bank, 2016).

6.2.3 Water sector

The development and transfer of water technologies in Africa relates mainly to water resource management, demand management, water storage, early warning systems and disaster preparedness, and clean water supply and sanitation.

- There was an increase in the use of water resource management between 2017 and 2020 (Integrated Water Resource Management [IWRM] 2022). In 2017, 67 per cent of sub-Saharan African countries scored very low, low, or medium-low, and 28 per cent of countries scored medium-high or high, but in 2020 52 per cent of countries scored medium-low or less, and 44 per cent scored medium-high or above. Smart technologies incorporating sensors, monitors and geographic information systems are also being explored.
- On water monitoring and decision support, a pan-African Water and Sanitation Sector Monitoring and Reporting System (WASSMO) was developed in 2015 (UNEP-Danish Hydraulic Institute 2018; UNEP-Danish Hydraulic Institute 2020). This is the first sub-Saharan-Africa-wide automated, web-based system that captures data on water and sanitation across the 55 Member States using harmonized indicators to monitor progress.
- Early warning systems are being introduced region-wide in West Africa (including in Benin, Burkina Faso, Ghana, Mali and Togo) (Volta Basin Authority 2022). Currently, only four countries in Africa have end-to-end drought forecasting or warning services at a full or advanced capacity level (Nyathi 2022).
- To provide a clean water supply and better hygiene, water treatment technologies (conventional and new) are being introduced. This includes technologies such as filtration, flocculation, coagulation, ozonation and chlorination, as well as adsorption-desorption technologies enhanced by nanotechnology. Good examples of this can be found in Zambia, Mozambique and South Africa (Community Research and Development Information Service [CORDIS] 2020).

6.2.4 Innovation and technology hubs

- Nearly 618 technology hubs have been identified and mapped across Africa (Briter Intelligence 2019) including incubators, accelerators, innovation hubs and co-working hubs. The majority of these are concentrated in Kenya, South Africa, Nigeria and Egypt, followed by Tanzania, Ghana, Ivory Coast, Morocco and Tunisia.
- In 2022, the International Finance Corporation (IFC) and the World Bank recognized pan-African climate technology initiatives, start-ups and social enterprises driving innovation and development (Viva Technology 2022). These are mainly in Kenya, Uganda, South Africa, Nigeria, Morocco and Egypt. The innovations ranged from an accessible solar cold-chain (Koolboks) to a tech platform for commuters using electric vehicles and e-motorbikes (Easy Matatu), to financial and microinsurance services for smallholders (Agro Tech Plus), to solar e-waste awareness and safe disposal services (WEEE). M-Pesa is also a major African innovation that forms an important component of the business model for many climate technologies. It is important to note that several of these start-ups and enterprises are led by international entrepreneurs and backed by grant, donor and philanthropic funding.

Box 5. Case: Large-scale renewable energy technologies in sub-Saharan Africa: Towards net-zero futures

Africa's economic development stands out due to its heavy reliance on primary industries such as agricultural and extractive activities. Secondary industries have evolved from the oil, gas and coal sectors, specifically in West and Southern Africa. Fossil fuel reserves in Africa are not being rapidly depleted, enabling technological and institutional path dependencies in the use, trade and beneficiation of fossil fuels. Consequently, infrastructure development has historically evolved in line with trends in foreign extractive industries and African state agency.

Despite its abundant fossil fuel and mineral resources, the African continent is closest to a net-zero future. Energy-related emissions account for less than 4 per cent of the global burden, despite steady increases since the 1990s. The demand for new electricity infrastructure is enormous, with 43 per cent of Africa's population, a total of 600 million people, having no access to electricity (IEA 2022).

Africa's energy transitions are currently at a crossroads. The declining cost of renewable energy technology and abundant wind, solar and hydro resources create a unique opportunity for the continent to close current technology gaps through renewables and to remain on a low-emissions development pathway. Renewable energy auctions in South Africa, Uganda and Zambia have attracted investment renewable energy projects at low cost (IRENA 2018). Independent power producers in South Africa alone have added more renewable energy capacity through competitive bidding programmes in just four years than the rest of sub-Saharan Africa has in more than 20 years (Eberhard et al. 2016). While the renewables market is growing, progress in the large-scale introduction of renewable energy remains politically contested, however, despite significant coalitions in support of it (Rennkamp 2019).

Despite Africa's potential to leapfrog fossil fueled energy technologies, over twenty new coal plants in various planning stages are currently listed on Global Coal Plant Tracker, with uncertainties around their financial feasibility and the role of Chinese funding. The promotion of coal plants by small political elites can create rent seeking behavior and stranded assets. The case of Kenya's proposed "clean" coal plant at a UNESCO heritage site in Lamu island well exemplifies the contestations around large infrastructure programmes, conservation, and socio-economic development (Nyabola 2017, Boulle 2019, Ayhan & Jacob 2020).

Successful regional integration will be critical for clean energy futures in Africa. While the East and Central African Energy Pools remains relatively low carbon intensive and the oil boom in West Africa is slowing down, Africa's largest power pool in Southern Africa (SAPP) continues to rely heavily on fossil fuels. Recent evidence finds that wind- and solar-dominated electricity systems can meet the growing demand at lower cost than a fossil fuel or hydropower dominated technology mix, without increasing GHG emissions in the SAPP (Chowdhury et al, 2022). Hence, renewables can set African countries on a low-emissions development pathway capable of powering the continent's ambitious human development agenda and creating universal energy access. The main risk to realizing clean energy futures resides in the political decision-making process, which needs to prioritize the rapid and inclusive roll-out of renewable energy for the benefit of all.

Solar power plant in Africa
Shutterstock

Box 6. Case: Affordable irrigation for climate adaptation in sub-Saharan Africa

Sub-Saharan Africa faces increasingly erratic rainfall patterns with intense storms and long dry spells. This directly impacts livestock and crop farmers, who predominantly depend on rainfall for water. Climate adaptation interventions in the region focus on technologies for water storage, rainwater harvesting and irrigation. Additionally, experiments are being conducted with "soft" technologies for water resource planning in uncertain circumstances, for example water accounting, remote sensing-based early warning systems and adaptive planning approaches.

Nevertheless, big, top-down investments such as large dams and schemes remain the conventional. These investments take years to plan and implement, are not adaptive and are relatively expensive. These schemes are typically designed based on a projected future and are unable to meet the needs of changing climate, stakeholder demands and the socio-political environment, as documented in the high failure rate and the frequent need for scheme rehabilitation (Merrey, D. 2020, Kikuchi et al., 2021).

In contrast, most of the increase in irrigated areas in sub-Saharan Africa since 2000 has been developed as a result of smallholder farmers' own investments in affordable technology (Wiggins & Lankford 2019). This is seen across the region, including in Kenya, Tanzania, Ethiopia, Ghana, Nigeria and Burkina Faso. Farmers with plot sizes as small as 0.1 ha and up to larger 2–5 ha plots use a variety of technologies to cultivate seasonal vegetables to meet their subsistence and cash needs. Depending on the local context, they use gravity-based irrigation from rivers, lakes and reservoirs, or lift supplies from surface-water and groundwater (well) points. Water is lifted manually or using small portable petrol or diesel motorized pumps in combination with water conveyance mechanisms such as hosepipes, spray tubes, or drip lines. Affordable petrol- and diesel-powered pumps imported from China and India have helped to boost this activity further. However, uncertainty over fuel prices has increased interest in solar-powered pumps for irrigation. At a price point of about USD 1,000 per 0.2 ha of irrigated area, small solar-powered pumps are used by smallholders (Duker et. al. 2020) and recognized as climate-smart investments. But affordability remains a challenge.

The private sector is an important player in the import and distribution of technology, while international donors and non-governmental organizations support investment by farmers (for example the USAID-funded Feed the Future Innovation Lab for Small-Scale Irrigation).

Direct, unsubsidized sales of solar irrigation pumps to smallholders are limited. Developing regional manufacturing and assembling capacity will make it possible to attract new actors. For smallholders, affordable finance is one of the biggest barriers. Ongoing experimentation by non-governmental organizations and the private sector in innovative financing (Gebrezgabher et al. 2021), such as pay-as-you-go solutions (in Mozambique, Ghana, Uganda and Kenya, for example), revolving funds, matching grants and rent-to-own schemes, offers promising possibilities. Greater affordability and adaptive, supportive mechanisms are therefore needed to accelerate farmer uptake.

Water pumps and solar panels
kaninw Shutterstock

Box 7. Case: Agriculture – Digitization and digital technologies*

Across the African continent, farmers are using digital technologies to improve yields, transport goods, receive and deliver services, learn new skills and connect themselves across widely dispersed geographic areas. This development primarily rests on the growth in mobile telephone connection, the decrease in mobile Internet prices, advances in data analytics and exchange and the growing demand for agri-smart solutions. Farmers are using Facebook and WhatsApp, among other social media platforms, for information sharing such as farming advice and prices. However, for these farmers, there are high expectations that more advanced services and digital tools covering solutions to improve agricultural productivity, market links, data analytics and intelligence and financial inclusion can significantly improve agricultural output and efficiency and drive economic development.

With a vibrant entrepreneurial environment, Kenya has seen a boom in agri-tech start-ups and investments in agriculture (Food and Agriculture Organization of the United Nations [FAO] and the International Telecommunication Union [ITU] 2022). More than 80 per cent of emerging digital agricultural technologies are concentrated in Kenya, South Africa, Nigeria and Ghana. Kenya is a leading agri-technology hub, with 58 digital agricultural technologies operational in the country (World Bank 2020). In Kenya, Ghana and South Africa, this is combined with a strong business incubation environment (e.g. the climate innovation centres in Kenya and Ghana and the Meltwater Entrepreneurial School of Technology in Ghana) and a high level of capacity for innovation (FAO and ITU 2022). Nigeria's innovation ecosystem is led by the private sector and sees limited engagement from other ecosystem players or the Government (an exception being the non-profit Wennnovation Hub that has supported several digital agri-tech start ups). This differs from Kenya, which serves as a top destination for development partners, impact investment capital, the private sector and philanthropic investors (World Bank 2020). For example, Mercy Corps' AgriFin Accelerate Program has been an anchor partner for the DigiFarm platform, providing funding, knowledge and networking opportunities for partnership formation (World Bank 2020). In addition, venture funds such as Novastar Ventures, Safaricom Spark Venture Fund and Village Capital are focusing on investing in early-stage technology innovations.

While development partners are supporting tech innovation and business incubation, most educational systems have yet to integrate information and communications technology training into their curricula, and most schools in the rural areas of sub-Saharan Africa have limited or no access to connectivity and information technology infrastructure. Digital skills training is mainly provided by private educational institutions, mobile network companies and online platforms, or through programmes and projects launched by development organizations, all of which are mostly concentrated in urban areas (FAO and ITU 2022). While South Africa is far ahead in terms of research spending in agriculture as a percentage of GDP (at 2.78 per cent), Ghana's and Kenya's research spendings cleave close to their optimal levels, according to the Agricultural Science and Technology Indicators Intensity Index, which factors in the structural characteristics of each country's economy and agricultural sector (Beintema and Stads 2017). Also, in research–industry collaboration, Kenya and South Africa currently score high (FAO and ITU 2022).

* Select content has been extracted from the FAO and ITU report (2022) and the World Bank report (2020).

6.3 INITIAL REFLECTIONS

This section provides initial reflections on the developments highlighted in the previous sections and identifies the favourable elements as well as gaps in the enabling environment.

6.3.1 Energy

Over the past two decades, renewable energy technologies such as solar and wind have reached market maturity, with wind power growing primarily at the utility scale and solar power growing at both the utility scale and the community and household scale. Costs have rapidly decreased and technological innovation alongside conducive policy environments and social acceptability has led to these technologies gaining a high degree of feasibility, viability and desirability. **The private sector plays a strong role in the wind and solar sectors, where early donor support combined with private sector experimentation, followed by the development of conducive policy environments (tax exemptions, target-setting and procurement programmes, auctions schemes and so on), targeted regulation (product and installation standards), has enabled the diffusion of these technologies (Eberhard et al., 2016, Bhamidipati et. al., 2020, GOGLA, 2022)**. These developments together with business model innovation (smart metering and pay-as-you-go models) and targeted skill programmes have led to the increased market-based diffusion of solar photovoltaics (PV) and wind at the scale we see today in many African countries.

While progress in technology development and transfer is greater in some regions (e.g. eastern and southern Africa), it lags in others (e.g. western Africa and parts of central Africa) as well as in policy implementation, needed knowledge and capacity development, goal-setting by governments and in the support for entrepreneurship and industry and market formation. **This calls for differentiated approaches from governments and donors**. Leading countries such as South Africa still need strong political commitments in phasing out coal. **Countries that are front runners in the energy transition need to be equipped to reap the benefits of the markets in terms of industrial development, local job creation and socioeconomic development more broadly (RES4Africa et al. 2022, Magala et. al., 2022)**, whereas countries that do not yet see a mature market for renewables should be supported in establishing such markets, including energy sector-related policies and regulation, standards, taxation schemes, knowledge build-up, learning and lobbying networks as well as the legitimization and broader build-up of trust in the growth potential to attract investors.

6.3.2 Agri-water nexus

While we have seen private markets evolving in the renewable energy sector, this has not been the case to the same extent in the water and agriculture sectors. **Agri-water technologies are mainly driven by large government- and donor-led schemes or to some extent by individual uptake by farmers** who can afford to buy these technology solutions through direct sales or through end-user-financed pay-as-you-go options. However, market-led diffusion is not taking place at scale, compared with renewable energy technologies. Irrigation systems are complex and the diffusion of irrigation technologies depends on the existence of a high level of knowledge and practical skills among government, support agencies, system designers, technology suppliers, extension services, craftspeople and farmers. **Limited expertise among farmers and inadequate public extension services are among key constraints to market formation for small-scale irrigation solutions**. Furthermore, irrigation equipment and support services mean high upfront capital costs for smallholders, and the gap between smallholders' capital needs and the availability of loan products represents a major constraint to the diffusion and uptake of these technologies (Hornum and Bolwig 2020).

We do see a trend in the demand for equipment and consultancies from government- and donor-supported irrigation projects stimulating the entry of more technology suppliers into these markets, as well as private technology providers undertaking a range of activities including training, financial packaging and knowledge dissemination (e.g. Sunculture in Kenya), which are important indicators of market formation taking place. However, **the enabling environment in terms of polices and regulations as well as available finance is lacking. There is a need to develop and support finance solutions for both technology suppliers and end users as well as to improve import regulations, standards and subsidies, as we have seen for example with solar PV products**.

6.3.3 Digital technologies and technology hubs

The density of entrepreneurial activity in digital agricultural solutions is high in some countries (Kenya, Ghana, South Africa and Nigeria) compared with the rest of the continent. However, the density of entrepreneurial hubs may be a reflection of global enthusiasm around digital solutions and thus **a sign of the market still being in the formative stage where technology development and experimentation are taking place**, instead of a reflection of technology implementation taking place at scale. Early-stage digitization start-ups are constrained by low access to capital, leading to high reliance on personal funds, donor grants and foreign venture capital. In the countries indicated above, as well as in Uganda and Senegal, dedicated climate innovation and business incubation centres are operational, functioning through donor finance providing business support – to start-ups, entrepreneurs and small to medium-sized enterprises – for developing innovative solutions to climate change as an effort to support continuous market formation. Similarly, for the agrifood sector, green innovation centres are operating in 14 African countries supporting smallholder farmers.

At the same time **there is a lack of digital skills and adequately digitally skilled workers, which places a constraint on the development of the digital sector.** There are several opportunities to address gaps in the enabling environment, such as specific policies and governance mechanisms that enable agricultural innovations and diffusion. This could, for example, include **legal frameworks for data protection in relation to a digital marketplace, as well as upgrading curricula, expanding coverage and placing additional focus on digital skills in technical and vocational education and trainin**g (FAO and ITU 2022).

To sum up, we see progress in climate technology development and transfer, but at a varied pace across sectors, countries and regions. Progress is driven by national policies, institutions and actors in combination with international efforts. Certain sector-specific innovation policies are well developed and streamlined across most African countries, particularly in the energy sector, including feed-in-tariffs, VAT exemptions and product standards. Particularly in the solar sector, we see a high degree of implementation of standards and certification both regarding products as well as technical training and skills programmes. Some countries stand out when it comes to the implementation of clean energy policies, scale of markets and levels of diffusion. These include Kenya, South Africa, Ghana, Nigeria, Egypt and Morocco, the same countries with the highest concentrations of innovation hubs and start-up ecosystems around climate technology innovations. **The patterns and developments regarding technology progress are less visible in agricultural and water technologies.**

The availability of data impacts our understanding of technology development and transfer progress. Data is more available for some sectors, technologies and regions than for others. While data on solar and wind development in the relatively advanced African countries (e.g. Kenya, South Africa and Nigeria) is readily available, there is very limited data on mitigation technologies and progress in other countries such as ones in central Africa (including Central African Republic, Congo, Cameroon, Gabon and Chad). Agricultural policies and climate-smart agriculture technology practices are **primarily spread across semi-arid and arid climatic subregions. CGIAR holds the most comprehensive data on agriculture gathered over the past two decades, but these also reflect sporadic interventions with large variations across countries.** Technologies that support a shift from rain-fed farming to irrigated farming (such as fuel-powered or solar pumps) have helped farmers in climate adaptation, and these are diffused more in regions with erratic and unreliable rainfall. Despite a growing focus on interventions around water resource management and water harvesting and storage, most countries in Africa are lacking remote-sensing-based early warning systems for improved disaster preparedness (e.g. for floods).

When looking at interventions, projects and programmes to diffuse climate technology, progress is often observed in pilot projects, demonstrations or initial deployment rather than in scaled up interventions. Some scale-up programmes are being driven by international organizations (e.g. the World Bank, Energy Sector Management Assistance Program and International Water Management Institute [IWMI]) in select countries. **However, given the varied developmental contexts among countries in Africa, replicability and scalability have yet to become a reality for several technologies and sectors.** Strengthening absorptive and innovative capacities, as well as maximizing socioeconomic benefits at the country level, must complement efforts towards this reality.

The linkages between science and innovation policy and the development and transfer of climate technologies are somewhat vague and not clearly understood, except for the specific cases where science technology hubs are densely concentrated, enabling strong progress in technology diffusion (e.g. in Kenya, South Africa, Nigeria and Egypt). The innovation ecosystem is more evolved in some countries in Africa. **The stages of technology development and innovation also entail, in many cases, deeper levels of industrialization linked strongly to economic development (Pigato et al. 2020), which varies across countries in Africa.**

6.4 KEY MESSAGES

The chapter presented a snapshot of certain macrotrends around climate technologies and selected case briefs on three sectors in the context of some African countries and regions, allowing for initial reflections on progress and gaps regarding technology development and transfer. As a scoping report, the aim has been to provide information in broad terms, further refine the framing and deep dive into select cases in future series. Drawing on the trends, case briefs and initial reflections, some key messages are highlighted below:

- While climate technology diffusion has progressed significantly in many African countries, overall there remain large disparities between countries in their ability to deploy technology to meet their climate goals. Efforts to support and accelerate climate technology action in Africa, therefore, must take these differences into account.

- Data on technology development and transfer is more available for some sectors, technologies and regions than for others but generally data remains sparse and sporadic. Within mitigation technologies, we see some level of data consistency and availability in some countries, whereas on adaptation technologies, data availability is far less systematic and consistent.

- There is an important intersection between climate action and development needs where major developmental issues, including access, equitable development and distributional aspects, need to be addressed alongside the implementation of climate technologies. Addressing the tensions between climate action and development priorities as well as maximizing synergies among them will likely be key to continued and accelerated action towards climate technology progress in the African context (and indeed, more broadly, in other developing countries).

- There are a wide range of international and national actors involved in technology development and transfer, but they often seem to be operating independent programmes focused on implementing a specific activity, project or programme by that particular entity. Greater coordination and synergy among the relevant international and national actors, driven by a focus on an issue- or needs-driven approach, will likely enhance the effectiveness of climate action as well as the efficient use of resources.

- There is a need for more systematic analytical interrogation into technology "progress" that reflects on local experiences, spillovers and outcomes beyond facts and descriptions. At the same time, more systematic data collection and knowledge-sharing are lacking across countries for mitigation technologies, especially for adaptation technologies, and are thus sorely needed.

ANNEX A: INDICATORS USED IN SURVEY

Table 5: Survey indicators

Category	Indicator description
Policy	Integration in national climate policy
	Integration in economic and financial policy
	Integration with sustainable development policy
	Integration in education and training policy
	Integration in innovation policy
	Integration in broader policy framework (sector, subsector level)
Institutions	Public/private sector entities engage in advancement of technology
	Institutional structures (coordination, processes) for technology
	Institutional links between policy and different levels of governance
	Institutional links between policy and industry, markets, private sector
	Institutional links between policy and int. markets, industry, private sector
Legal	Overarching legal and regulatory framework into which technology is integrated
	Laws, regulations established and enforced for the technology
Social	Civil society institutions, networks, processes support the technology
	Communication campaigns on technology
	Links between policy and indigenous peoples and local communities
	Links between policy and gender perspectives, roles
	Users, consumers, lifestyles, preferences, etc. play role in technology
	Consumer preferences, habits, traditions assist in behaviour change
Finance	Integration of policy in national budget
	Funding from industry, markets, private sector
	Institutional links between policy and international sources of public finance
	Institutional links between policy and international sources of private finance

Selecting indicators

Indicators of feasibility within the dimensions are contextual and differ slightly between adaptation and mitigation options, and for adaptation options, between regions. The indicators were selected based on a review of scholarship and expert consultation and had underlying questions to guide the assessment of feasibility, depicted in the third column of table 6 and the second column in table 7. For Africa, the indicators were adjusted slightly to fit within regional context (section 4).

In the AR6 report, for adaptation, the assessment generally focused on whether or not a given indicator was a barrier, and whether or not there are knowledge gaps. For mitigation, the assessment focused on whether indicators hindered or facilitated implementation. In defining some indicators as facilitators, the mitigation FA recognizes that some options are outperforming the options they aim to replace – e.g. solar PV being cheaper than fossil fuels. Similarly, mitigation options can also have co-benefits – e.g. electric vehicles and solar energy reduce local and regional air pollution – which also increases the potential for a mitigation option to be rapidly implemented and at a larger scale.

A clear line of sight to the underlying evidence and literature was developed for each decision throughout the assessment. This involved carefully tracking the evidence for each option and mapping them onto specific indicators.
As per IPCC guidance, confidence language was applied to each assessment based on the amount of, and the level of agreement on, the evidence.

Combining indicators for an overall feasibility score

Options can also be assigned an overall assessment. For the adaptation options, for each feasibility dimension, overall feasibility was assessed as the arithmetic mean score of the relevant underlying indicators. Based on this, dimensions were classified as having insignificant barriers (2.5–3), mixed or moderate barriers (1.5–2.5) or significant barriers (below 1.5) to feasibility. Indicators assessed as not applicable (NA), limited evidence (LE), or no evidence (NE) were not included in this overall assessment. This mapping process is important for transparency purposes. This is shown in figure 1.

For mitigation options, overall feasibility per dimension was assessed as follows. Each indicator that serves as a barrier was counted as two negative points, each indicator serving as a facilitator was counted as two positive points, and indicators serving as both a barrier and a facilitator received one negative and one positive point. Next, the total number of negative and positive points were computed for each dimension-option combination relative to the maximum possible score per dimension for each option. The resulting score reflects the extent to which each feasibility dimension would in general facilitate or constrain the deployment of the relevant mitigation option, providing an easier overview of the extent to which feasibility dimensions inhibit or facilitate deployment of the option.

Ensuring robustness and transparency

All assessments drew on three rounds of internal review to ensure coherence, coverage and balance. Reviews included adding literature and improving the coverage of studies – e.g. to include evidence from different countries, peer-reviewed and grey literature – and removing any perceived biases. Each option's indicator-level assessment was validated by at least three authors. If indicator-level assessment differed, it was reconciled between the team of authors based on the literature each individually reviewed. As indicated above, for regional or contextual differences in option-level feasibility, text was used to explain the differentiating factors (see context column in table 7).

Ideally, a systematic review would be conducted to comprehensively document relevant literature (e.g. see Berrang-Ford et al. 2015). However, when resources or time are limited, semi-systematic assessment approaches could be followed, such as standard practices of literature review – searching databases to achieve reference saturation – followed by careful and iterative reference checking, expert suggestions and internal peer review. The latter was employed for the AR6 reports due to time constraints resulting in assessing several thousand unique references for SR1.5, AR6 Working Group 2 and AR6 Working Group 3. When the process is downscaled at national or subnational level, where references are limited to allow an extensive literature review, the assessment can rely on expert consultations and grey literature.

Table 6. Dimensions, indicators and guiding questions for adaptation options from Working Group 2 IPCC AR6

Dimensions	Indicators	Questions asked with adaptation indicators
Economic	Microeconomic viability	What are the economic costs and trade-offs of the option? (High costs correspond to low feasibility) Is the financial/economic potential (related to lack of financial resources, economic structures, and economic mobility) for the adaptation option a constraint? OR Are there known economic barriers? Does the option perform well on costs with minimal trade-offs with costs on other options?
	Macroeconomic viability	Does the option lead to higher economic productivity and performance?
	Socioeconomic vulnerability reduction potential	Does the option reduce socioeconomic inequalities?
	Employment and productivity enhancement potential	Does the option employ many people or increase a system's productivity increase under the option?
Technological	Technical resource availability	Are the technology and associated human, financial, administrative resources needed for an adaptation option available?
	Risks mitigation potential	Can the option reduce the likelihood and/or consequences of risks?
Institutional	Political acceptability	Is the option politically acceptable? Does the option reflect stakeholder perceptions about the meaning and purpose of adaptation?
	Legal, regulatory feasibility	Is the option appropriate to jurisdictional context? Is it challenging to implement the legal changes needed for the option? Are there known legal and regulatory barriers?
	Institutional capacity and administrative feasibility	Would current institutions be able to implement the option? Is the option administratively supported? Are human resources to support implementation of adaptation option clearly identified? Are responsibilities delineated for managing the implementation of the option?
	Transparency and accountability potential	Are policy goals and targets for the option explicitly articulated, monitoring and evaluation protocols set up to track implementation and transparent reporting mechanisms in place to synthesize progress and gaps?
Social	Social co-benefits	Are there health and education benefits from the option? Does the option minimize negative trade-offs with other development policy goals and identify positive synergies with other policy goals?
	Sociocultural acceptability	Is there sociocultural resistance to the option? Does the option typically find acceptance within existing sociocultural norms and utilize diverse knowledge systems including Indigenous and local knowledge?
	Social and regional inclusiveness	Are different social groups and remote regions included in the option? Does the adaptation option adversely affect vulnerable groups or other areas?
	Intergenerational equity	Does the option compromise the ability of future generations to meet their own needs in any way? (More compromise leads to lower feasibility)
	Gender equity	Does the option hinder or further gender equity goals?
Environmental	Ecological capacity	Does the option enhance supporting, regulating or provisioning ecosystem services in any way?
	Adaptive capacity/ resilience building potential	Does the option enhance the ability of systems, institutions and humans to adjust to potential damage, take advantage of opportunities, or respond to consequences or does the option contribute to resilience building (ability to cope with stressors and reorganize to maintain structures and functions and retain capacity to transform)?
Geophysical	Physical feasibility	Is the physical potential for the adaptation option a constraint?
	Land use change enhancement potential	Does the option enhance carbon stocks? (e.g. through forest restoration)
	Hazard risk reduction potential	Does the option reduce number of people/systems exposed to a hazard?

Table 7. Dimensions and indicators to assess barriers and facilitators of implementing mitigation options from Working Group 3 IPCC AR6

Dimensions	Indicators
Geophysical feasibility: availability of required geophysical resources	• Physical potential: extent to which there are physical constraints to implement the option • Geophysical resource availability (including geological storage capacity): availability of resources needed to implement the option (e.g. minerals, fossil fuels) • Land use: claims on land when implementing the option
Environmental-ecological feasibility: impacts on the environment	• Air pollution: changes in air pollutants, such as NH4, CH4, fine dust • Toxic waste, ecotoxicity and eutrophication • Water quantity and quality: changes in amount of water available for other uses, including groundwater • Biodiversity: including changes in area of conserved primary forest or grasslands that affect biodiversity, and management aimed at conservation and maintenance of land carbon stocks
Technological feasibility: extent to which the required technology can be implemented at scale quickly	• Simplicity: is the option technically simple to operate, maintain and integrate • Technology scalability: can the option be scaled up quickly to a meaningful level • Maturity and technology readiness: Research and Development (and time) needed to implement the option
Economic feasibility: financial costs and benefits and economic effects	• Costs now, in 2030 and in the long term, including investment costs (investments per ton CO2 avoided), costs in USD/tCO2-eq and hidden costs • Effects on employment and economic growth
Sociocultural feasibility: public engagement and support, and health, well-being and distributional effects	• Public acceptance: the extent to which the public supports the option and will change their behaviour accordingly • Effects on health and well-being (excluding environmental-ecological impacts) • Distributional effects: equity and justice across groups, regions and generations, including security of energy, water, food and poverty
Institutional feasibility: institutional capacity, governance structures and political support	• Political acceptance: extent to which politicians and governments support the option • Institutional capacity and governance, cross-sectoral coordination: capability of institutions to implement and handle the option, and coordinate it with other sectors, stakeholders and civil society • Legal and administrative capacity: extent to which supportive legal and administrative changes can be achieved

Interpreting the results of a FA

An indicator-level assessment captures if a certain indicator poses a barrier, or, in the case of mitigation, facilitates the feasibility of the option. For both adaptation and mitigation, the feasibility assessments show where the largest barriers for implementing a given option exist through dimensions and specific indicators. In this way, a FA points towards possible first steps that can be taken to improve the potential for implementation of any given option. The FA can also be used to identify options that have an overall low feasibility, indicating that these barriers would need to be addressed. Thus, a decision maker may consider assigning an option with many barriers a lower ranking or priority, as far as the option is not perceived to be desirable in the light of local contexts. Options with many facilitating factors could be ranked higher as they are more easily implemented. There are also options with co-benefits, as identified in indicators that specifically refer to them – e.g. other environmental impacts – and are mostly linked with sustainable development and SDGs specifically. The performance on the indicators can also provide guidance on where there may be trade-offs. Some indicators may both inhibit and facilitate the implementation of mitigation options, such as if an option requires more land use in one region but less land in other regions.

ANNEX C: SYNERGIES AND TRADE-OFFS OF MITIGATION OPTIONS WITH ADAPTATION (FOCUSED ON ENERGY AND AGRICULTURE TECHNOLOGIES)

Table 8. Synergies and trade-offs of adaptation technologies with mitigation

Adaptation option	Implications for mitigation	
	Synergies	Trade-offs
Resilient power infrastructures	**(strong)** Strong synergies with mitigation goals as resilient infrastructure allows power generation systems to continue operations without disruption (or minimal disruptions). This is especially important for renewable energy systems. **(strong)** In rural landscapes, resilient power infrastructure ensures electricity availability during emergencies and protects the communities from any malfunction of the infrastructure itself.	
Reliable power systems	**(strong)** Strong synergies with mitigation goals as reliable systems decrease the risk of disruptions and avoid the use of fossil fuels in cases where the main energy system is renewable energy, either centralized or decentralized.	
Improve water use efficiency	**(medium)** Improved water use efficiency increases generation efficiency in certain natural gas combined cycle plants (Pan et al. 2018), while at the same time improving fresh water use and ensuring that the ecological flows of water sources are not disturbed.The improved water use efficiency, for example, in community micro-hydroelectric plants allows for integrated water management across the watersheds that ensures water for irrigation, human consumption and other productive uses.	
Improved cropland management	**(medium)** Improved cropland management practices and technologies (e.g. tillage methods, water application and nutrient management) reduce greenhouse gas emissions significantly but depend on technology type and the stage of its adoption – e.g. other environmental impacts – e.g. direct rice seeding can reduce methane emissions while laser land levelling can reduce energy used for irrigation. **(strong)** Combinations of improved cropland practices like reduced or no-tillage, nutrient management and residue recycling have a higher rate of soil organic carbon sequestration of 427.9 kg/ha/yr under a rice-rice system, e.g. in north-east India (Yadav et al. 2019) while optimized nutrient management through organic farmyard manure and other micronutrients increases soil organic carbon in maize-mustard cropping systems by up to 9.7 per cent. **(strong)** Improved soil management practices increase soil organic carbon (SOC) stocks – e.g. other environmental impacts – e.g. in the North China Plain such practices have increased SOC by 56–73 per cent compared to initial stocks in the 1980s. Implementation of such practices in just 27 per cent of China's cropland increased the annual carbon sequestration amount in surface soils to 10.9 Tg C/year, contributing an estimated 43 per cent of total carbon sequestration in China's croplands. **(medium)** Emerging cropland management practices like minimal tillage, stubble retaining and nutrient management increase SOC stocks, but the extent varies with site-specific conditions. **(strong)** Integrated soil-crop system management can reduce greenhouse gas emissions by 19 per cent and carbon footprint by 30 per cent compared to traditional practices. **(strong)** Integrated soil-fertility management and conservation agriculture contribute to climate change mitigation by reducing SOC losses. **(strong)** Conservation agriculture has an estimated annual carbon sequestration benefit of 143 Tg C per year.	**(weak)** Improved cropland management practices aimed at increasing carbon sequestration in agriculture soils could lead to increased greenhouse gas emissions if the nitrogen inputs are not managed effectively. By 2060, around half of sites in Europe with carbon-mitigating agricultural practices could turn into a net source of greenhouse gases. **(weak)** The increase in SOC through climate-smart agriculture practices could be offset by increased nitrous oxide emissions within corn belt states in the United States of America.

Continued next page

Adaptation option	Implications for mitigation	
	Synergies	Trade-offs
Agroforestry	**(strong)** Agroforestry is generally found to have positive impacts on mitigation by improving carbon sequestration.	**(weak)** Thinning of natural forest canopy to establish agricultural crops such as cocoa or coffee seedlings retains more trees than in a monoculture plantation but carbon stocks are diminished. In addition, over reliance on vegetation-based adaptation strategies may lead to an increased susceptibility to wildfires which release large amounts of carbon into the atmosphere.
Water use efficiency and water resource management	**(medium)** Water-saving irrigation practices such as alternate wetting and drying and soil water potential (SWP) have mitigation co-benefits through CH4 and NO2 emissions reductions. SWP also significantly reduced seasonal methane emissions by around 30 per cent when combined with better fertilizer application. **(medium)** Integrated watershed management sequesters carbon by enhancing soil carbon storage through better yields and residue returns. **(strong)** Drip irrigation can reduce cumulative CH4 flux by 194 per cent in a year when compared to conventional flooding in rice cultivation in Japan (Fawibe et al. 2019), increase 22 per cent CH4 uptake and reduce N2O emissions by 14.6 per cent, while microirrigation saves energy use by 58 per cent compared to conventional gravity irrigation.	**(weak)** Some water use efficiency practices can increase water use and, thus, energy demand.

Table 9. Synergies and trade-offs of adaptation technologies with mitigation

Mitigation options	Implications for adaptation	
	Synergies	**Trade-offs**
Solar energy	**(strong)** When produced on-site, solar power provides electricity supply in the case of grid failure due to natural disasters or very high temperatures shutting off large power stations and overheating the transmission/distribution network. Solar can also have on-site storage. Solar technologies such as thermal and solar cooking can also contribute to on-site energy security. **(strong)** Solar can be complementary to other renewable energy sources, reducing system vulnerabilities.	**(strong)** Generation of e-waste; land requirement; competition with food production; vulnerability of local communities due to large-scale plants, although the impact is highly location- and context-specific.
Carbon dioxide capture and storage (CCS)	**(weak)** Diversification of livelihood for people in areas of geological sequestration; potential for just transition away from high polluting industry jobs.	**(medium)** Even though large-scale deployment of CCS is not necessarily found to lead to higher long-term water consumption from fossil fuel power generation compared with systems without CCS, for coal-fired power plants located in water-scarce areas the additional water consumption required by CCS could create competition with other human activities for local water resources, potentially undermining local adaptation efforts.
Bioenergy and bioenergy with carbon capture and storage	**(strong)** Enhanced productivity when done properly as part of ongoing agriculture and forestry; enhanced waste recycling; enhanced income for farmers and forest owners when bioenergy is derived from residues and low quality wood; favours local employment; local energy that can compensate for fluctuations in wind and solar. Clear air quality improvement and reduced air pollution and non-CO2 emissions, if counterfactual is to burn residues in the field. **(weak)** When designed properly, bioenergy plantations can serve as connectivity pathways between nature areas. **(strong)** Modern bioenergy provides clean energy access. **(strong)** Bioelectricity complements variable renewable energies and reservoir hydropower as a balancing power source, thus helping to ensure grid stability and quality, and in situations where hydro is limited due to drought. **(strong)** Clear air quality improvement if counterfactual is to burn residues in the field (SDG 3).	**(strong)** There are clear absolute limits to amounts of bioenergy feasible; if derived from very large (maldeveloped) bioenergy plantations then many risks and trade-offs occur with biodiversity pressure and loss, competition for food, food-water security risks and soil degradation due to overuse of fertilizers. **(strong)** Poorly chosen sites for energy crops can reduce water availability for agriculture and settlements.
Energy storage for low-carbon grids	**(strong)** Increases energy security; produces employment opportunities.	**(weak)** Generation of e-waste if recycling/circular economy not implemented; impacts of mining of metals for battery components and unequal access to precious minerals.
Biomass crops for bioenergy, biochar and other bio-based products	**(strong)** Enhanced income for farmers and forest owners (SDG 1, 8). **(strong)** Strategically integrated energy crops can enhance landscape heterogeneity, produce wood for buildings and other applications, support bioeconomy and biodiversity conservation (SDG 15) and reducing the risk of flooding, soil erosion and impacts of drought.	**(strong)** Large-scale biomass plantations could impact conservation of biodiversity (SDG 15), compete for land with food production (SDG 2) and compete for water in dry areas or pollute water through heavy fertilizer use (SDG 6, 3, 14).

REFERENCES

A. Demirgüç-Kunt, T. B. (2008). Household Access to Finance : Poverty Alleviation and Risk Mitigation. In *Finance for All*: Policies and Pitfalls in Expanding Access (pp. 99-142)

Abdel-Latif, A. (2015). Intellectual property rights and the transfer of climate change technologies: Issues, challenges, and way forward. *Climate Policy*, 15(1), 103–126. https://doi.org/10.1080/14693062.2014.951919

Afokpe, P. M., Phiri, A. T., Lamore, A. A., Toure, H. M., Traore, R., & Kipkogei, O. (2022). Progress in climate change adaptation and mitigation actions in sub-Saharan Africa farming systems. *Cahiers Agricultures*, 31, 4. https://doi.org/10.1051/cagri/2021037

African Energy Commission (2019). *Designing the African energy transition: An approach for social and economic transformation in a climate compatible manner.* https://au-afrec.org/sites/default/files/2022-02/4%20AFREC%20Designing%20the%20African%20Energy%20Transition.pdf

Ameli, N., Dessens, O., Winning, M., Cronin, J., Chenet, H., Drummond, P., Calzadilla, A., Anandarajah, G., & Grubb, M. (2021). Higher cost of finance exacerbates a climate investment trap in developing economies. *Nature Communications*, 12, Article 4046. https://doi.org/10.1038/s41467-021-24305-3

Anadon, L. D., Chan, G., Harley, A. G., Matus, K., Moon, S., Murthy, S. L., & Clark, W. C. (2016). Making technological innovation work for sustainable development: Table S1. *Proceedings of the National Academy of Sciences*, 113(35), 9682–9690. https://doi.org/10.1073/pnas.1525004113

Arnold, J., Matoo, A., & Narciso, G. (2006). Services Inputs and Firm Productivity in Sub-Saharan Africa : Evidence from firm-level data. *World Bank Policy Research Working Paper*

Ayhan, S. H., & Jacob, T. Competing energy visions in Kenya: The political economy of coal. In *The Political Economy of Coal* (pp. 171-187). Routledge

Barnett, H. G. (1953). *Innovation: the basis of cultural change*. McGraw-Hill

Bartz-Zuccala, W., Taskin, Ö., Hos, T., Sangaré, C., & Horrocks, R. S. (2022). *Scaling up Blended Finance in Developing Countries*. Paris: OECD Publishing

Beck,T. R. C. (2014). Banking in Africa. In *The Oxford Handbook of Banking* (pp. 913-937)

Beintema, N. M., & Stads, G. J. (2017). *A comprehensive overview of investments and human resource capacity in African agricultural research*. International Food Policy Research Institute. https://www.ifpri.org/publication/comprehensive-overview-investments-and-human-resource-capacity-african-agricultural

Bernanke, S. (2011). Promoting Research and Development: *The Government's Role. At the Conference on "New Building Blocks for Jobs and Economic Growth*," . Washington DC: Board of Governors of the Federal Reserve System

Berrang-Ford, L., Pearce, T., & Ford, J. D. (2015). Systematic review approaches for climate change adaptation research. *Regional Environmental Change*, 15(5), 755-769

Bhamidipati, P. L., & Gregersen, L. E. (2020). Clean captive power: *Understanding the uptake and growth of commercial and industrial (C&I) solar PV in Kenya*. UNEP-DTU Partnership Technical Report. Retrieved from: https://unepccc.org/publications/clean-captive-power-understanding-the-uptake-and-growth-of-commercial-and-industrial-ci-solar-pv-in-kenya/

Bijker, W. E., Hughes, T. P., & Pinch, T. (2012). *The social construction of technological systems*. MIT Press

Blanco, G., de Coninck, H. C., Agbemabiese, L., Diagne, E. H. M., Anadon, L. D., Lim, Y. S., Pengue, W. A., Sagar, A., Sugiyama, T., Tanaka, K., Verdolini, E., Witajewski-Baltvilks, J., Reis, L. A., Babiker, M., Bai, X., Bekkers, R. N. A., Bertoldi, P., Burch, S., Cabeza, L. F., Winkler, H. (2022). Innovation, technology development and transfer. In P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (Eds.), *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–161). Cambridge University Press

Boulle, M. (2019). The hazy rise of coal in Kenya: The actors, interests, and discursive contradictions shaping Kenya's electricity future. *Energy Research & Social Science*, 56, 101205

Briter Intelligence. (2019). 618 active tech hubs in Africa. The backbone of Africa's tech ecosystem. https://briterbridges.com/618-active-tech-hubs

CA Global. (2017, 30 October). *Technological advancements rule agricultural development in Africa*. https://www.caglobalint.com/post/technological-advancements-rule-agricultural-development-in-africa-1

Chowdhury, A. F. M. K., Deshmukh, R., Wu, G. C., Uppal, A., Mileva, A., Curry, T., Armstrong, L., Galelli, S., & Ndhlukula, K. (2022). Enabling a low-carbon electricity system for Southern Africa. *Joule*, 6(8), 1826–1844. https://doi.org/10.1016/j.joule.2022.06.030

Colenbrander, S., Cao, Y., Pettinotti, L., & Quevedo, A. (2021). *A fair share of climate finance: Apportioning responsibility for the $100 billion climate finance goal*. ODI. https://odi.org/en/publications/a-fair-share-of-climate-finance-apportioning-responsibility-for-the-100-billion-climate-finance-goal/

Community Research and Development Information Service. (2020). *New technology provides clean water in Africa*. European Commission. https://cordis.europa.eu/article/id/415837-new-technology-provides-clean-water-in-africa

Crewe, E., & Axelby, R. (2013). *Anthropology of development: Culture, morality and politics in a globalised world.* Cambridge University Press

Croxatto, L. S., Hogendoorn, D., & Petersen, A. C. (2020). How networked organisations build capacity for anticipatory governance in South East Asian deltas. Futures, 116, Article 102512. https://doi.org/10.1016/j.*futures*.2020.102512

Cull, R., & Demirgüç-Kunt. (2013). *Banking the World: Empirical Foundations of Financial Inclusion*. 19-42

de Coninck, H., & Puig, D. (2015). *Assessing climate change mitigation technology interventions by international institutions*. *Climatic Change*, 131(3), 417–433. https://doi.org/10.1007/s10584-015-1344-z

de Coninck, H., & Puig, D. (2015). Assessing climate change mitigation technology interventions by international institutions. Climatic Change, 131(3), 417–433. https://doi.org/10.1007/s10584-015-1344-z

de Coninck, H., & Sagar, A. (2015). Making sense of policy for climate technology development and transfer. *Climate Policy*, 15(1), 1–11. https://doi.org/10.1080/14693062.2014.953909

de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A., Dong, W., Ford, J., Fuss, S., Hourcade, J. C., Ley, D., Mechler, R., Newman, P., Revokatova, A., Schultz, S., Steg, L., & Sugiyama, T. (2018). Strengthening and implementing the global response. In M. Allen, M. Babiker, Y. Chen, H. de Coninck, S. Connors, R. van Diemen, O. P. Dube, K. L. Ebi, F. Engelbrecht, M. Ferrat, J. Ford, P. Forster, S. Fuss, T. G. Bolaños, J. Harold, O. Hoegh-Guldberg, J.-C. Hourcade, D. Huppmann, D. Jacob, K. Jiang, K. Zickfeld (Eds.), *Global warming of 1.5°C: Summary for policymakers*. Cambridge University Press

Duker, A., Cambaza, C., Saveca, P., Ponguane, S., Mawoyo, T. A., Hulshof, M., Nkomo, L., Hussey, S., Van den Pol, B., Vuik, P., Stigter, T., & Van der Zaag, P. (2020). Using nature-based water storage for smallholder irrigated agriculture in African drylands: Lessons from frugal innovation pilots in Mozambique and Zimbabwe. *Environmental Science & Policy*, 107, 1–6. https://doi.org/10.1016/j.envsci.2020.02.010

Eberhard, A., Gratwick, K., Morella, E., & Antmann, P. (2016). *Independent power projects in Sub-Saharan Africa: Lessons from five key countries*. World Bank Group. https://openknowledge.worldbank.org/handle/10986/23970

Ekekwe, N. (2017, 18 May). How digital technology is changing farming in Africa. *Harvard Business Review*. https://hbr.org/2017/05/how-digital-technology-is-changing-farming-in-africa

Energy Regulators Association of East Africa. (2022, 17 May). *The cooking tariff: A gateway to convenient, clean and efficient cooking*. The Energy Regulator. https://theenergyregulator.com/the-cooking-tariff-a-gateway-to-convenient-clean-and-efficient-cooking/

Energy Sector Management Assistance Program. (2019). *Uganda clean cooking behavioral diagnostic*. World Bank. https://openknowledge.worldbank.org/handle/10986/31283

Fawibe, O. O., Honda, K., Taguchi, Y., Park, S., & Isoda, A. (2019). Greenhouse gas emissions from rice field cultivation with drip irrigation and plastic film mulch. *Nutrient Cycling in Agroecosystems,* 113(1), 51-62

Food and Agriculture Organization of the United Nations, & International Telecommunications Union. (2022). *Status of digital agriculture in 47 sub-Saharan African countries*. https://www.fao.org/3/cb7943en/cb7943en.pdf

Gebrezgabher, S., Leh, M., Merrey, D. J., Kodua, T. T., & Schmitter, P. (2021). *Solar photovoltaic technology for small-scale irrigation in Ghana: Suitability mapping and business models* (17). International Water Management Institute. https://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub178/rr178.pdf

Godinho, C., & Eberhard, A. (2019). Learning from power sector reform experiences: The case of Kenya (*Policy Research Working Paper 8819*). World Bank. https://openknowledge.worldbank.org/handle/10986/31561

Green, F., & Gambhir, A. (2020). Transitional assistance policies for just, equitable and smooth low-carbon transitions: Who, what and how? *Climate Policy*, 20(8), 902–921. https://doi.org/10.1080/14693062.2019.1657379

Guzmán, S., Dobrovich, G., Balm, A., & Meattle, C. (2022). *The state of climate finance in Africa: Climate finance needs of African countries*. Climate Policy Initiative. https://www.climatepolicyinitiative.org/wp-content/uploads/2022/06/Climate-Finance-Needs-of-African-Countries-1.pdf

Haselip, J., Hansen, U.E., Puig, D., Trærup, S., & Dhar, S. (2015). Governance, enabling frameworks and policies for the transfer and diffusion of low carbon and climate adaptation technologies in developing countries. In, *Climatic Change* 131, 363–370. https://doi.org/10.1007/s10584-015-1440-0

Hornum, S. T., & Bolwig, S. (2020). *The growth of small-scale irrigation in Kenya: The role of private firms in technology diffusion*. UNEP DTU Partnership. https://backend.orbit.dtu.dk/ws/files/223530158/The_Growth_of_Small_Scale_Irrigation_in_Kenya1.pdf

Hou, X., Morales, X. Z., Obuya, G. A., Bobo, D., & Braimoh, A. (2016). *Climate smart agriculture : successes in Africa* (English). World Bank Group. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/622181504179504144/climate-smart-agriculture-successes-in-africa

Integrated Water Resources Management. (2022). *IWRM Data Portal*. Retrieved October 25, 2022, from http://iwrmdataportal.unepdhi.org/countrydatabase

Intergovernmental Panel on Climate Change. (2000). *Methodological and technological issues in technology transfer: A special report of the Intergovernmental Panel on Climate Change*. Cambridge University Press

Intergovernmental Panel on Climate Change (2018). *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Cambridge University Press

Intergovernmental Panel on Climate Change (2022a). Climate Change 2022: *Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press

Intergovernmental Panel on Climate Change (2022b). Climate Change 2022: Impacts, adaptation, and vulnerability. *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/working-group/wg2/

Intergovernmental Panel on Climate Change. (2022c). *Assessment Report 6 Summary for Policy Makers. In Managing the risks of extreme events and disasters to advance climate change adaptation: Special report of the Intergovernmental Panel on Climate Change* (pp. 3–22). Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.003

Intergovernmental Panel on Climate Change. (2022d). *Africa. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1285-1455, doi:10.1017/9781009325844.011

International Center for Biosaline Agriculture. (2017, December 20). *Boosting food security in sub-Saharan Africa through solar-powered irrigation systems*. https://iiqp.biosaline.org/news/2017-12-20-6326

International Energy Agency. (2022). *Africa energy outlook 2022.* International Energy Agency. https://www.iea.org/reports/africa-energy-outlook-2022

International Monetary Fund (2022, October 13). *Investment and Capital Stock Dataset*. Retrieved from IMF Data Access to macroeconomic and financial data: https://data.imf.org/?sk=1CE8A55F-CFA7-4BC0-BCE2-256EE65AC0E4

International Renewable Energy Agency. (2018). *Renewable energy auctions: Cases from sub-Saharan Africa*. International Renewable Energy Agency. https://www.irena.org/publications/2018/Apr/Renewable-energy-auctions-Cases-from-sub-Saharan-Africa

International Renewable Energy Agency. (2020). *The renewable energy transition in Africa: Powering access, resilience and prosperity.* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/Renewable_Energy_Transition_Africa_2021.pdf

International Renewable Energy Agency. (2022). *Renewable Energy market analysis: Africa and its regions*. International Renewable Energy Agency & African Development Bank. https://www.irena.org/publications/2022/Jan/Renewable-Energy-Market-Analysis-Africa

Kendall, J. N. M. (2010). Measuring Financial Access around the World. *World Bank Policy Reserach Working Paper Series*

Kikuchi, M., Mano, Y., Njagi, T. N., Merrey, D., & Otsuka, K. (2021). Economic Viability of Large-scale Irrigation Construction in Sub-Saharan Africa: What if Mwea Irrigation Scheme Were Constructed as a Brand-new Scheme. *The Journal of Development Studies*, 57(5), 772-789

Kim, J., Shah, P., Gaskell, J. C., Prasann, A., & Luthra, A. (2020). *Scaling up disruptive agricultural technologies in Africa* (International Development in Focus). World Bank. https://openknowledge.worldbank.org/handle/10986/33961

Kojima, M., & Trimble, C. (2016). *Making power affordable for Africa and viable for its utilities*. World Bank. https://openknowledge.worldbank.org/handle/10986/25091

Kowalski, P., Rabaioli, D., & Vallejo, S. (2017). *International technology transfer measures in an interconnected world: Lessons and policy implications*. OECD Trade Policy Papers, No. 206, OECD. https://www.oecd-ilibrary.org/trade/international-technology-transfer-measures-in-an-interconnected-world_ada51ec0-en

Levine, R. (2001). International financial liberalization and economic growth. *Review of international economics*, 688-702

Lighting Global/ESMAP, GOGLA, Efficiency for Access, Open Capital Advisors (2022). *Off-Grid Solar Market Trends Report 2022: State of the Sector*. Washington, DC: World Bank. Retrieved from: https://www.gogla.org/off-grid-solar-market-trends-report-2022

Linham, M. M., & Nicholls, R. J. (2010). Technologies for climate change adaptation: Coastal erosion and flooding. In Adaptation: Coastal erosion and flooding (Issue January 2010), UNEP. https://tech-action.unepccc.org/wp-content/uploads/sites/2/2019/04/tnahandbook-coastalerosionflooding.pdf

Magala, J., Sembatya, E., Bitete, L., Bhamidipati, P. L., & Pedersen, M. B. (2022). *Unlocking support for local clean energy companies: insights from the solar PV industry in Uganda*. UNEP DTU Partnership

Maskus, K. (2004). *Encouraging International Technology Transfer.* UNCTAD-ICTSD Project on IPRs and Sustainable Development. Retrieved from https://www.files.ethz.ch/isn/111411/2010_01_encouraging-international-technology-transfer.pdf

Mazzucato, M. (2016). *From market fixing to market-creating: A new framework for innovation policy*. Industry and Innovation, 23(2), 140–156. https://doi.org/10.1080/13662716.2016.1146124

McGee, J., & Wenta, J. (2014). *Technology transfer institutions in global climate governance: The tension between equity principles and market allocation*. Review of European, Comparative and International Environmental Law, 23(3), 367–381. https://doi.org/10.1111/reel.12075

Merrey, D., 2020. *Large scale irrigation investments in sub-Saharan Africa: Is big beautiful?. Water Dissensus – A Water Altern*. Forum. Retrieved from: https://www.water-alternatives.org/index.php/blog/african-irrigation

Miyamoto, K., & Chiofalo, E. (2016). *Official Development Finance for Infrastructure: With a Special Focus on Multilateral Development Banks*. OECD Development Co-operation Working Papers

Möller, A. Okem, B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (2897–2930). Cambridge University Press

Moore, M. L., Olsson, P., Nilsson, W., Rose, L., & Westley, F. R. (2018). *Navigating emergence and system reflexivity as key transformative capacities: Experiences from a Global Fellowship program*. Ecology and Society, 23(2). https://doi.org/10.5751/ES-10166-230238

Morduch, J., Cull, R. J., & Demirgüç-Kunt, A. (Eds.) (2012). *Banking the World: Empirical Foundations of Financial Inclusion*. MIT Press. http://public.eblib.com/choice/publicfullrecord.aspx?p=3339554

Müller, J. (2003). Perspectives on technological transformation: a conceptual framework for technological analysis. In J. Kuada (Ed.), *Culture and Technological Transformation in the South*

Nyabola, N. (2017). Cashing in on Coal: Kenya's unnecessary power plant. *World Policy Journal*, 34(3), 69-75

Nyathi, M. (2022, September 9). Climate change and water — why early warning systems are key to communities' survival. *Mail & Guardian*. https://mg.co.za/environment/2022-09-09-climate-change-and-water-why-early-warning-systems-are-key-to-communities-survival/

Nygaard, I. and Hansen, U. (2015). *Overcoming barriers to the transfer and diffusion of climate technologies: Second edition*. UNEP DTU Partnership

Nygaard, I. and Hansen, U. (2015). *Overcoming barriers to the transfer and diffusion of climate technologies: Second edition*. UNEP DTU Partnership. https://tech-action.unepccc.org/wp-content/uploads/sites/2/2019/04/overcoming-barriers-to-the-transfer-and-diffusion-of-climate-technologies-2nd-ed-3rdmarch.pdf

Ockwell, D., & Byrne, R. (2016). Improving technology transfer through national systems of innovation: Climate relevant innovation-system builders (CRIBs). *Climate Policy*, 16(7), 836–854. https://doi.org/10.1080/14693062.2015.1052958

Olhoff, A. (2015). *Adaptation in the context of technology development and transfer*. Climate Policy, 15(1), 163–169. https://doi.org/10.1080/14693062.2014.873665

Organisation for Economic Co-operation and Development (2017a). *Investing in Climate, Investing in Growth*. Paris: OECD Publishing. doi:https://dx.doi.org/10.1787/9789264273528-en

Organisation for Economic Co-operation and Development, United Nations Environment Programme, & World Bank. (2018). *Financing Climate Futures: Rethinking Infrastructure*. Paris: OECD Publishing

Organisation for Economic Co-operation and Development. (2018a). *OECD Science, Technology and Innovation Outlook 2018: Adapting to Technological and Societal Disruption*. doi:https://dx.doi.org/10.1787/sti_in_outlook-2018-en

Organisation for Economic Co-operation and Development. (2022a, October 12). *Government Budget Allocations for R&D*. Retrieved from OECD Stat: https://stats.oecd.org/Index.aspx?DataSetCode=GBARD_NABS2007

Organisation for Economic Co-operation and Development. (2022b, October 12). *Creditor Reporting System (CRS)*. Retrieved from OECD.Stat: https://stats.oecd.org/

Organisation for Economic Co-operation and Development. (2022c). *Climate finance provided and mobilised by developed countries in 2016-2020: Insights from disaggregated analysis, Climate finance and the USD 100 Billion Goal*. Paris: OECD Publishing. doi:https://doi.org/10.1787/286dae5d-en

Organisation for Economic Co-operation and Development. (2022d). *OECD blended finance guidance for clean energy.* Paris: OECD Publishing

Organisation for Economic Co-operation and Development. (Forthcoming). *Greening developing country financial systems. An overview of approaches and insights on the role of development co-operation.* Paris: OECD Publishing

Pan, S. Y., Snyder, S. W., Packman, A. I., Lin, Y. J., & Chiang, P. C. (2018). Cooling water use in thermoelectric power generation and its associated challenges for addressing water-energy nexus. *Water-Energy Nexus*, 1(1), 26-41

Pigato, M. A., Black, S. J., Dussaux, D., Mao, Z., McKenna, M., Rafaty, R., & Touboul, S. (2020). *Technology transfer and innovation for low-carbon development (International Development in Focus)*. World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/33474/9781464815003.pdf

Polzin, F., Sanders, M., Steffen, B., Egli, F., Schmidt, T. S., Karkatsoulis, P., Fragkos, P., & Paroussos, L. (2021). The effect of differentiating costs of capital by country and technology on the European energy transition. *Climatic Change*, 167, Article 26. https://doi.org/10.1007/s10584-021-03163-4

Renewable Energy Policy Network for the 21st Century. (2022). *Renewables 2022. Global status report*. REN21 Secretariat. https://www.ren21.net/gsr-2022/

Rennkamp, B. (2019). Power, coalitions, and institutional change in South African climate policy. *Climate Policy*, 19(6), 756–770. https://doi.org/10.1080/14693062.2019.1591936

RES4A, IRENA, and UNECA. (2022). *Towards a prosperous and sustainable Africa: Maximising the socio-economic gains of Africa's energy transition*. RES4Africa Foundation, Rome. Retrieved from: https://www.irena.org/publications/2022/Feb/Towards-a-prosperous-and-sustainable-Africa

Reutemann, T. (2018). *Disintermediating the Green Climate Fund*. In A. Marke (Ed.), Transforming climate finance and green investment with blockchains (pp. 153–163). Academic Press. https://doi.org/10.1016/B978-0-12-814447-3.00011-2

Ruckelshaus, M., Reguero, B. G., Arkema, K., Compeán, R. G., Weekes, K., Bailey, A., & Silver, J. (2020). Harnessing new data technologies for nature-based solutions in assessing and managing risk in coastal zones. *International Journal of Disaster Risk Reduction*, 51. https://doi.org/10.1016/j.ijdrr.2020.101795

Scoones, I., Stirling, A., Abrol, D., Atela, J., Charli-Joseph, L., Eakin, H., Ely, A., Olsson, P., Pereira, L., Priya, R., van Zwanenberg, P., & Yang, L. (2020). Transformations to sustainability: Combining structural, systemic and enabling approaches. *Current Opinion in Environmental Sustainability,* 42, 65–75. https://doi.org/10.1016/j.cosust.2019.12.004

Singh, C., Bazaz, A., Ley, D., Ford, J., & Revi, A. (2020). Assessing the feasibility of climate change adaptation options in the water sector: Examples from rural and urban landscapes. *Water Security*, 11, 100071. https://www.sciencedirect.com/science/article/abs/pii/S2468312420300110

Sovacool, B. K., Hess, D. J., Amir, S., Geels, F. W., Hirsh, R., Rodriguez Medina, L., Miller, C., Alvial Palavicino, C., Phadke, R., Ryghaug, M., Schot, J., Silvast, A., Stephens, J., Stirling, A., Turnheim, B., van der Vleuten, E., van Lente, H., & Yearley, S. (2020). Sociotechnical agendas: Reviewing future directions for energy and climate research. *Energy Research and Social Science*, 70. https://doi.org/10.1016/j.erss.2020.101617

Steffen, B. (2020). Estimating the cost of capital for renewable energy projects. *Energy Economics*, 88, 104783. doi:10.1016/j.eneco.2020.104783

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy*, 42(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Technology Executive Committee. (2015). TEC Brief #6. *Enhancing access to climate technology financing. United Nations Framework Convention on Climate Change*. http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TEC_documents/204f400573e647299c1a-7971feec7ace/ea65db0ca9264cdbaefeb272dd30b34c.pdf

Technology Executive Committee. (2020). *Draft paper on enabling environments and challenges to technology development and transfer identified in TNAs , NDCs and CTCN technical assistance*. United Nations Framework Convention on Climate Change. https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tn_meetings/0ec5dc7fc4a045468f11e360347f7da7/8a6bc538ce414d21a2a5efa460ebfe39.pdf

Technology Executive Committee. (2022). *Enabling environments and challenges to technology development and transfe*r. United Nations Framework Convention on Climate Change. https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

Thomas, A., Serdeczny, O., & Pringle, P. (2020). Loss and damage research for the global stocktake. *Nature Climate Change*, 10, Article 700. https://doi.org/10.1038/s41558-020-0807-z

Thompson, V. A. (1965). *Bureaucracy and innovation*. Administrative Science Quarterly, 10, 1–20. https://www.jstor.org/stable/2391646

Trærup, S. L. M., Gregersen, L., & Knudsen, C. (2018). *Mapping barriers and enabling environments in technology needs assessments, nationally determined contributions, and technical assistance of the climate technology centre and network*. UNEP DTU Partnership

Trisos, C.H., Adelekan, I.O., Totin, E., Ayanlade, A., Efitre, J., Gemeda, A., Kalaba, K., Lennard, C., Masao, C., Mgaya, Y., Ngaruiya, G., Olago, D., Simpson, N.P. and Zakieldeen, S. (2022) Africa. In H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press

United Nations Conference on Trade and Development. (2003a). *Africa's technology gap: Case studies on Kenya, Ghana, Uganda and Tanzania.* United Nations Conference on Trade and Development . Retrieved from https://unctad.org/system/files/official-document/iteipcmisc13_en.pdf

United Nations Conference on Trade and Development. (2003b). *Investment and technology policies for competitiveness: Review of successful country experiences*. United Nations Conference on Trade and Development. Retrieved from https://unctad.org/system/files/official-document/iteipc20032_en.pdf

United Nations Conference on Trade and Development. (2003c). *Transfer of Technology for Successful Integration into the Global Economy*. United Nationas Conference on Trade and Development. Retrieved from https://unctad.org/system/files/official-document/iteipc20036_en.pdf

United Nations Conference on Trade and Development. (2004). *Facilitating Transfer of Technology to Developing Countries: A Survey of Home-Country Measures*. United Nations Conference on Trade and Development . Retrieved from https://unctad.org/system/files/official-document/iteipc20045_en.pdf

United Nations Environment Programme (2022). *Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies.* Nairobi. https://www.unep.org/emissions-gap-report-2022

United Nations Environment Programme. (2021). *Global progress on adaptation finance. In Adaptation gap report 2021* (pp. 26–37). United Nations Environment Programme. https://doi.org/10.18356/9789280738957c008

United Nations Environment Programme-Copenhagen Climate Centre (2022). Technology transfer for climate change mitigation and adaptation. *Analysing needs and development assistance support in technology transfer processes*. Paris: OECD Publishing

United Nations Environment Programme-Danish Hydraulic Institute. (2018, September 17). UNEP-DHI's online tool for implementing United Nations' SDGS wins top award in Tokyo. *DHI Worldwide*. https://worldwide.dhigroup.com/global/news/2018/09/unep-dhi-online-tool-for-implementing-un-sdgs-wins-top-award-in-tokyo

United Nations Environment Programme-Danish Hydraulic Institute. (2020, August 25). Africa water sector and sanitation monitoring and reporting system. *UNEP-DHI Centre*. https://www.unepdhi.org/decision-support-systems/

United Nations Framework Convention on Climate Change (2021a). *Glasgow climate pact. Decision 1/CMA.3*. United Nations Framework Convention on Climate Chang

United Nations Framework Convention on Climate Change (2021b). *Draft paper on UNFCCC on enabling environments and challenges to technology development and transfer identified in TNAs, NDCs and CTCN technical assistance, and relevant TEC Briefs*. United Nations Framework Convention on Climate Change. https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tn_meetings/b424150e-4b9a4a3ab26df459d94c0d20/17d0f4143d9e4b9faa55bf6490c28c85.pdf

United Nations Framework Convention on Climate Change. (2022). *Introduction To climate finance*. https://unfccc.int/topics/climate-finance/the-big-picture/introduction-to-climate-finance

United Nations. (1990). Transnational Corporations and the *Transfer of New and Emerging Technologies to Developing Countries.* UN Centre on Transnational Corporations. Retrieved from https://digitallibrary.un.org/record/106383?ln=fr

van de Wetering, R., Mikalef, P., & Helms, R. (2017). Driving organizational sustainability-oriented innovation capabilities: A complex adaptive systems perspective. *Current Opinion in Environmental Sustainability*, 28, 71–79. https://doi.org/10.1016/j.cosust.2017.08.006

van Kerkhoff, L., & Szlezák, N. A. (2016). The role of innovative global institutions in linking knowledge and action. *Proceedings of the National Academy of Sciences of the United States of America*, 113(17). https://doi.org/10.1073/pnas.0900541107

Viva Technology (2022, May 2). *Viva Techology, IFC announce 45 emerging start-ups with biggest impact potential in Africa to compete for the 2022 AfricaTech Awards*. https://vivatechnology.com/media/press-releases/viva-techology-ifc-announce-45-emerging-start-ups

Volta Basin Authority. (2022, March 9). *Early warning systems hold the key to disaster management in West Africa*. https://abv.int/en/early-warning-systems-hold-the-key-to-disaster-management-in-west-africa/

Watson, C., & Schalatek, L. (2019). *Climate finance fundamentals 2: The global climate finance architecture*. Heinrich-Böll-Stiftung. https://climatefundsupdate.org/wp-content/uploads/2020/03/CFF2-2019-ENG-DIGITAL.pdf

Wiggins, S., & Lankford, B. (2019). *Farmer-led irrigation in sub-Saharan Africa: synthesis of current understandings*. DFID-ESRC Growth Research Programme. https://cdn.odi.org/media/documents/DEGRP-Synthesis-Farmer-led-Irrigation.pdf

World Bank. (2022a, October 12). *Research and Development Expenditure* (% of GDP). Retrieved from World Bank Data: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS

World Bank. (2022b, October 12). *Global Financial Development Database*. Retrieved from World Bank DataBank: https://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database

Yadav, G. S., Lal, R., Meena, R. S., Babu, S., Das, A., Bhowmik, S. N., ... & Saha, P. (2019). Conservation tillage and nutrient management effects on productivity and soil carbon sequestration under double cropping of rice in north eastern region of India. *Ecological Indicators*, 105, 303-315

Young, O. (2017). *Governing complex systems*. MIT Press

ACRONYMS

AfDB	African Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
AFR100	African Forest Landscape Restoration Initiative
AGRA	Alliance for a Green Revolution in Africa
AR6	IPCC Sixth Assessment Report
BdC	Banque du Caire
BECCS	Bioenergy with carbon capture and storage
CAADP	Comprehensive Africa Agriculture Development Programme
CCS	Carbon dioxide capture and storage
CCUS	Carbon capture, utilisation and storage
CGIAR	Formerly Consultative Group for International Agricultural Research
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
COP	Conference of the Parties
COVID-19	Coronavirus disease 2019
CSA	Climate-smart Agriculture
CSP	Concentrated Solar Power
CTCN	Climate Technology Centre and Network
CTPR	CTPR-Climate Technology Progress Report
DNV	Det Norske Veritas
EAP	East Asia & Pacific
ECA	Europe and Central Asia
ECO-FEI	Environmental Compliance Office - Federation of the Egyptian Industries
EE	Energy Efficiency
EGP	Egyptian pound
EPAP	Egyptian Pollution Abatement Programme
EV	Electric Vehicle
FA	Feasibility Assessment
FAO	Food and Agriculture Organization of the United Nations
GBARD	Government Budget Allocation to research and development
GCF	Green Climate Fund
GCO	Grøn Circulær Omstilling
GDP	Gross Domestic Product
GBARD	Government Budget Allocations for Research and Development
GEF	Global Environment Facility
GGF	Green for Growth Fund
GHG	Greenhouse Gas Emissions
GNI	Gross National Income
IBM	International Business Machines Corporation
ICBA	International Center for Biosaline Agriculture
ICT	Information and Communications Technology
IEA	International Energy Agency
IFC	International Finance Corporation
ILSSI	Innovation Lab for Small-Scale Irrigation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on climate change
IT	Information technology
ITF	International Transport Forum
ITU	International Telecommunication Union
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
kfW	Kreditanstalt für Wiederaufbau ("Credit Institute for Reconstruction")
LAC	Latin America and the Caribbean
LE	Low Evidence
LIC	Low Income Country
LMIC	Lower Middle-Income Country

LPG	Liquified Petroleum Gas
MCSCUA	Makueni County Sand Conservation and Utilization Authority
MDA	Multi-Donor Account
MENA	Middle East and North Africa
MEST	Meltwater Entrepreneurial School of Technology
NA	Not Applicable
NAIP	National Agriculture Investment Plan
NDA	National Designated Authorities
NDC	Nationally Determined Contribution
NDP	National Development Plan
NE	No Evidence
NGO	Non-Governmental Organisation
NRM	Natural Resource Management
NSI	National Systems of Innovation
OECD	Organisation for Economic Co-operation and Development
PAYG	Pay-as-you-go
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PwC	PricewaterhouseCoopers
PV	Photovoltaics
R&D	Research and Development
RE	Renewable Energy
REIPPP	Renewable Energy Independent Power Producer Procurement Programme
SA	South Africa
SAPP	Southern African Power Pool
SDG	Sustainable Development Goals
SECI	Solar Energy Corporation of India
SEMED	Southern and Eastern Mediterranean
SME	Small and medium-sized enterprises
SR15	IPCC Special Report on Global Warming of 1.5°C
SSA	Sub-Saharan Africa
SUN	Scaling Up Nutrition
SWM	Sustainable Water Management
SWP	Soil Water Potential
TAF	Technical Assistance Facility
TEC	Technology Executive Committee
TNA	Technology Needs Assessment
UK	United Kingdom
UMIC	Upper Middle-Income Country
UNEP	United Nations Environmental Programme
UNEP-CCC	United Nations Environment Programme-Copenhagen Climate Centre
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar
VAT	Value-Added Tax
WAAPP	West Africa Agricultural Productivity Program
WASSMO	Water and Sanitation Sector Monitoring and Reporting System
WB	World Bank
WG	Working Group
WMO	World Meteorological Organization
WRI	World Resource Institute

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