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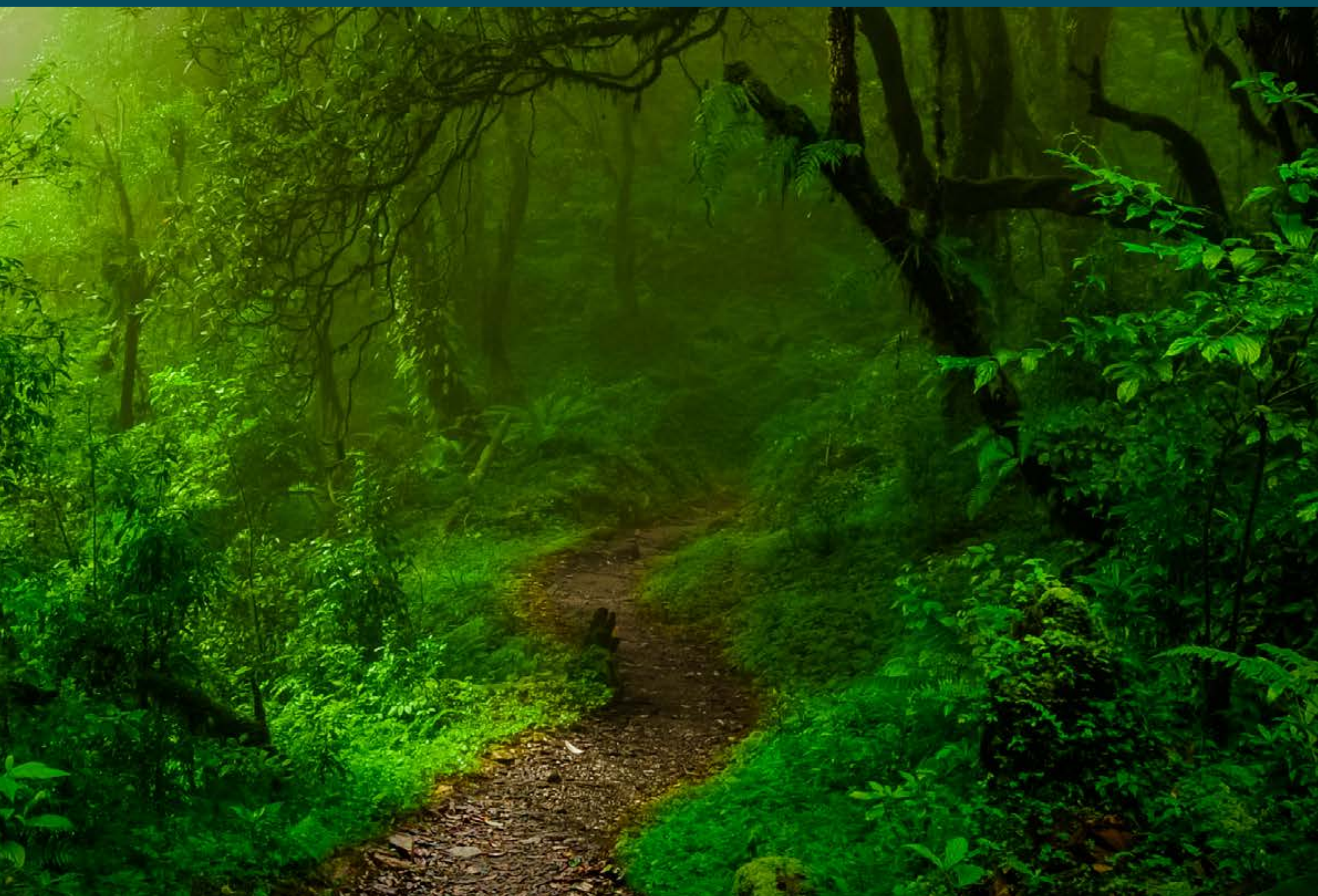
CLIMATE TECHNOLOGY CENTRE & NETWORK

UNEP DTU PARTNERSHIP

Scaling up investment in climate technologies

Pathways to realising technology development and transfer in support of the Paris Agreement



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Scaling up investment in climate technologies

Pathways to realising technology development and transfer in support of the Paris Agreement

Editor

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Innovative technologies are critical to our response to the climate crisis and are often an integral part of national climate plans. Technologies enable us to reduce greenhouse gas emissions while driving economic growth and industrial development, strengthening livelihoods and enhancing resilience. For example, a range of reliable renewable energy technologies such as wind and solar are central to climate change mitigation strategies. Technologies are also helping us adapt to the adverse effects of climate change, such as coastal zone defences, drought-resistant crops, early warning systems and water efficient irrigation. Technology is a key driver in the transition to more sustainable development pathways across a multitude of sectors, including food, water, energy, and urban systems.

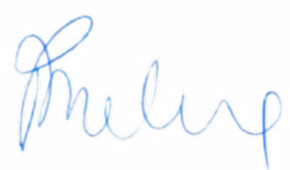
Within the United Nations Framework Convention on Climate Change (UNFCCC), the role and importance of technologies has received clear and consistent support from Parties to the Convention, for over 20 years. Under the Paris Agreement, this is articulated in the Technology Framework under Article 10, paragraph 4. This past year marks the third year of operationalisation of the Technology Framework, which has provided a structure through which to align the activities of UNFCCC bodies under the Technology Mechanism – the Technology Executive Committee and the Climate Technology Centre and Network (CTCN) – with the objectives of the Paris Agreement. The key themes of the Technology Framework, which this publication speaks to, are innovation; implementation; enabling environment and capacity building; collaboration and stakeholder engagement and support. The CTCN is the implementation arm of the UNFCCC and plays a key role as matchmaking partner for developing countries seeking technical assistance, capacity-building and knowledge for technology transfer.

A common starting point for pursuing ambitions in this area are the Technology Needs Assessments (TNAs), which aim to strengthen countries' abilities to analyse and prioritize climate technologies, guiding them towards implementation of Nationally Determined Contributions (NDCs) to the Paris Agreement and achievement of the Sustainable Development Goals (SDGs). Since 2009, UNEP DTU Partnership and UNEP have led the implementation of the GEF-funded Global TNA project in close to 100 countries.

Among Parties to the UNFCCC, there is now a broad understanding and agreement on *what* is needed in terms of technology development, uptake and diffusion to tackle climate change. Moreover, there are well-proven and effective policies and strategies in place to enable a radical transformation. However, there is far less clarity on *how to implement them, at scale*. These issues are the main focus of the latest collection of the Technology Perspectives, compiled and edited by UNEP DTU Partnership, drawing on years of research and country-specific technical assistance projects.

This publication brings together a unique collection of examples that provides real-world insights into various experiences, and their innovation and potential to effect transformational change, serving as inspiration for *what works and what could work*, as the world seeks to scale up investment in low-emission and climate resilient technologies.

Susanne Pedersen, Director of UNEP DTU Partnership (UDP)



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EDITORIAL

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Introduction

This edition of the 'Technology Perspectives' is produced and published in collaboration with the Climate Technology Centre and Network (CTCN) and the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The basic idea of these publications is to bring together a diverse group of authors to offer their evidence-based views and opinions around a common set of questions, applied to their technology or sector-specific area of expertise. In doing so we hope this collection stimulates, or contributes to, relevant debates in the area of climate technology development and transfer in the Global South.

In conceiving this publication, we started by asking ourselves how do we close the gap between technology needs and implementation towards the achievement of Nationally Determined Contributions (NDCs) to the Paris Agreement? What are the pathways to realising technology development and transfer in support of the NDCs? And what are the main opportunities for, and constraints to, progress? To a large extent, these questions reflect our experience and insights from the Technology Needs Assessments (TNA), mandated in Article 10 of the Paris Agreement, which UNEP and UNEP DTU Partnership (UDP) have helped complete in almost 100 countries since 2009[i].

We define 'implementation' as something broader than investment in low-carbon and climate resilient development, though investment is ultimately what is needed, at scale, if countries are to meet their NDC targets. Reflecting upon our work in delivering research-based advisory services to developing countries, we can already identify some of the main drivers of this transition, and the implications for a range of stakeholders.

At the highest level, much of our work seeks to understand the relative influence of top-down government-driven policy and planning as well as a diverse set of bottom-up push and pull factors that influence technology agendas, supply and demand. What is the interplay between these two levels or spheres, where and how do we see this in practice? And can we interrogate this with technology-specific examples, from both climate change mitigation and adaptation-side ambitions?

While COVID-19 has hit hard, it has also underscored the urgency of meeting global goals and stepping up ambition and action, including on investment decisions regarding technology implementation. These issues can be captured as an over-arching question, with a few sub questions:

- What are the driving forces behind actual technology transfer and implementation in developing countries, and by what mechanisms is this achieved?
  - How can we close the gap between national, regional and global climate technology needs and actual implementation? Who are the responsible parties from the global to local levels?
  - How are local needs taken into account, including the interests and preferences of technology end-users? Is this important? If so, why?
  - How do we create the conditions for large-scale investment, to enable and incentivise the far larger flows of public and private capital?

By asking these broad questions to our contributing authors we have sought insights into the practical value of government-led processes, and how they influence or link to public and private investment decision making at the project level.

Several articles in this edition focus on cleaner energy technologies, central to global climate change mitigation efforts, where we note the fast pace of socio-technical and economic change that has occurred[ii]. However, it is important to recognise the inherent limitations (past and present) of market forces in kick-starting technological transitions[iii]. For example, the work of Professor Mariana Mazzucato has shed light on the critical role of the state in creating new markets and pushing socially and environmentally beneficial technologies along the innovation-cost curve[iv]. She has further called for mission-oriented financing and large-scale public and private resource mobilisation to meet the needs (and scale) of the climate change challenge, acknowledging the inherent uncertainty, cost and often long timeframes for bringing the required innovations to market.[v]

Indeed, it is clear that new governance models and political commitments are required to support the diffusion of technologies in an efficient and inclusive manner, at sufficient scale. Public and transnational actors, including development agencies, have played – and will continue to play – a central role in both developed and developing countries[vi].

Our research and experience reveal that technological, market and social innovation must be conceptualised in concert, and in practice we observe this when working with our partner countries[vii]. For example, the TNA process has allowed us to observe how ideas and arguments are framed and deployed through otherwise objective multi-criteria and market analysis methodologies. Countries have a sovereign right to steer their technology pathways, pursue national development goals, and support a global agenda to tackle climate change with common but differentiated responsibilities, as laid out in the Paris Agreement.

In practice, we observe the early-stage processes of socio-technical lock-in - or path dependency - as it manifests within the technical working groups of government-led projects that in turn influence the political discourse within our partner countries. This interdependence reveals how governments steer economies down different technology pathways as the outcome of a mix of politics, policies, institutions and luck (defined as unintended consequences, either positive or negative). Such nationally determined development processes reflect cultural specificities, political ideologies or agendas, economic constraints and the realities of human capacities and financial resources. The net effect is a set of mixed outcomes, where some countries make progress on climate action faster than others. This may result from existing privileges or competitive advantages, though much can be said for the power of clear vision, effective leadership and/or collective action, e.g. a mix of top-down and bottom-up decisions and changes in behaviour.

Consequently, there is no one-size-fits-all technological solution or transition pathway, and all technical "solutions" must coalesce within the specific local socio-political and institutional context, influenced by cultural norms, attitudes and assumptions that filter otherwise objective data and scientific analysis. The expanding field of sustainability transitions research has thus far focused more on the developed world[viii]. We need a greater focus on the Global South. Further, we echo calls to see beyond the predominance of the science-policy-behavioural change pathways, to embrace what Nightingale et. al. (2020) refer to as "ontological pluralism", i.e. new ways of conceptualising society, climate and environment[ix].

Thus, we present the articles in this publication as an offering of deeper and more nuanced understandings of how technology transitions can occur and how best to navigate these in the Global South. We conclude with a call for more co-produced research, possibly through South-led projects bringing together key researchers and 'real world' practitioners in this area. The UNFCCC Technology Mechanism is well positioned to drive such an effort, enabling partnerships between academic institutions, international agencies, governments and in-country stakeholders to design and deliver research-based advisory. All of this is crucial if we are to inform scientific decision making, as a means to scale up investment in climate technologies.

The articles

We open this edition of the Technology Perspectives with an article led by Dr. Kandeh Yumkella, former Special Representative of the UN Secretary-General for Sustainable Energy for All, on the pressing need to solve the clean cooking conundrum in Africa. The delivery of clean and modern cooking solutions is a somewhat protracted challenge, one that has significant climate change as well as human health and development impacts. The article explores the technology options that meet both the competing needs of various SDG7 targets and the challenge of achieving net zero carbon development. In doing so, the authors confront the 'mutual neglect' in the political economy of clean cooking, looking for realistic pathways aligned with NDC policy and planning.

To support their arguments Yumkella et. al. present some case studies to demonstrate the significance of unintended or indirect benefits from technological innovation and growth in unrelated markets. These include the emergence of highly efficient Electric Pressure Cookers (EPCs) and the cost reductions in batteries driven by growth in global electric vehicle markets, both of which have stimulated the uptake of electric cooking in Africa. Indeed, EPC technology appears to be doing for cooking what the LED light bulb did for lighting, e.g. offering a high quality of service provision at a fraction of the power demand of incumbent technologies, thus lending itself to off-grid and renewable sources of power. The authors conclude with a call for more harmonised thinking and action on electrification and clean cooking policy, planning and investments. They argue that this is necessary if governments and their development partners are to deliver modern energy cooking services to the 4bn people who currently do not have access to them.

Following the application-specific analysis of the opening chapter is an article from Peter Storey et. al. of the Private Financing Advisory Network (PFAN). This is the first of two articles dedicated to the critical role of finance as a driver of climate technology transfer. Here, the PFAN authors reflect on their work with financing Small and Medium-sized Enterprises (SMEs) operating in the clean technology sectors in Least Developed Countries. They note that the creation or expansion of new public funding pools and donor-led financing facilities has stimulated the growth of commercial financing in the private sector, leveraged by financial innovation, enabling some technologies to move into the mainstream, at scale.

However, despite these positive trends, Storey et. al. argue that the amount of financing that reaches SMEs in the least developed countries continues to fall short of what is needed. They argue that local projects and businesses offer the greatest (and often lowest-cost) potential to deliver net emissions reductions and deliver pre-emptive climate change adaptation. The article offers various recommendations for expanding these market opportunities, including the need to expand the provision of blended finance, combining varying levels of risk-return investors with grant funding and technical assistance for SME project developers. The authors also highlight the importance of data generation, collection and interpretation as a means to create new investment opportunities, especially where the bundling of assets and lower financial scale thresholds are needed to invest in bottom-of-the-pyramid energy access technologies.

In the third article Deepa Pullanikkatil (national NDC coordinator) and Wilfred Nxumalo (department of forestry), both working at the Ministry of Tourism and Environmental Affairs in the Kingdom of Eswatini, walk us through the driving forces in the design and launch of an ambitious plan to plant 10 million trees in the country within 5 years. The authors discuss the benefits of this 'low-tech' solution to addressing both climate change mitigation and adaptation needs, which was prioritised by Eswatini's Technology Needs Assessment in 2016. However, it was not until mid-2020 that the government began to mobilise resources and implement the plan, as part of COVID-19 recovery and resilience building for climate change.

The authors describe how the simple, low-tech and inexpensive adaptation technology of tree planting was prioritised through a mix of top-down political will, volunteerism and bottom-up community action. Within a short period, a large number of indigenous, fruit and selected non-invasive trees were planted in the country, including the growth of "mini forests" in urban areas for the first time in Eswatini. As with many articles in this collection, the authors focus their analysis on the 'how' as opposed to the 'what' of climate technology diffusion, offering valuable insights for other low-income countries keen to replicate this positive experience.

Staying in Africa, our fourth contribution comes from Dr. Maxwell Otim Onapa, Director of Science, Research and Innovation at the Ministry of Science, Technology and Innovation in Uganda and Deborah Kasule, Head of Outreach and Information Management at the Uganda National Council for Science and Technology. They provide a detailed and technology-specific analysis of how the Ugandan State has driven efforts to reduce the vulnerability of its population, environment and economy through implementation of climate change adaptation actions aligned with its NDC targets.

Specifically, Onapa and Kasule leverage the results of the recently concluded TNA to chart a course to scaling up investment in the prioritised technologies of rooftop solar PV systems and rooftop water harvesting as optimal technology options in the energy and water sectors respectively. They use these two technologies as case studies and explore the barriers - or "roadblocks" - that hinder their transfer and adoption as well as core elements of an enabling framework that can help overcome the barriers to investment in large-scale technology rollout.

The fifth article offers a very different perspective on, and definition of, technology-driven solutions to climate change. In this article, Meropi Paneli and Giovanni Serritella, of the European Commission, lead a discussion on the EU's Copernicus Infrastructure and technologies for Earth Observation. With inputs from a range of technical experts, they explain how the Copernicus Infrastructure provides unparalleled opportunities to track all aspects of sustainable development more effectively, enabling the design and implementation of public and private actions to achieve agreed ambitions, including NDCs.

They discuss the economic benefits of earth observation technologies and how the provision of free and openly available environmental information is key to the effective planning and implementation of disaster preparedness, response, risk reduction, and climate change adaptation strategies. The article offers a detailed case study of the Philippines, where the EU is supporting the Government in its efforts to build technical capacities at national and local levels on the use of spatial data, in particular from remote sensing systems for the ultimate benefit of local communities.

Switching continents again, the sixth article in this compilation comes from Argentina where Marina Recalde and Daniel Bouille of the Bariloche Foundation discuss the power of bottom-up and multi-stakeholder approaches to improving the uptake of sustainable household energy technologies. Their analysis draws on various examples of local projects and years of on-the-ground experience, offering a perspective that neatly connects the top-down and bottom-up spheres of decision-making, similar to the article from Eswatini. Recalde and Bouille provide insights from community-led clean energy and energy efficiency projects that secured higher levels of ownership and local buy-in, compared to more 'top-down' initiatives often funded by distant and disconnected development partners and donors. Again, the emphasis is on the 'how' aspects of successful climate technology uptake, thus providing valuable lessons and recommendations for project developers in other developing countries.

The penultimate article is authored by Dr. Jiska de Groot of the African Climate and Development Initiative, University of Cape Town. Her contribution focuses on technology transfer and implementation through investment in human capacity, as exemplified in a case study analysis of the off-grid renewable energy sector in Africa. The need for investment in human capital is an issue raised by other authors in the publication, for example Storey et. al. and Onapa and Kasule. However, de Groot tackles the topic head-on, arguing that greater human capacity comprises an essential part of the solutions to achieve NDCs and various SDG targets, especially for new or expanding technologies and markets. She shows us how investment in skills and on-the-ground expertise development remains a largely overlooked form of technical and financial assistance, and one that is impeding the rollout and scale-up of technology transfer and implementation in many developing countries.

We close this edition of the Technology Perspectives with a concise overview of the various forms and sources of blended finance available for investments in climate technologies, crucial to charting pathways to implementing the NDCs. The analysis comes courtesy of Thomas Thorsch Krader, Renewable Energy Specialist at the African Development Bank, who unpacks the everyday finance terminology for a non-specialist audience. He focuses mostly on the role of patient and concessional funding from government or multilateral sources, key to de-risking projects and, subsequently, crowding in private capital. In doing so, Krader speaks to some of the key ideas and arguments advanced by Mazzucato on the role and importance of blended (public and private) resource mobilisation, appropriate to the nature and scale of the climate change challenge. This is of fundamental importance, given all the uncertainties, costs and often long pathways to realising technology development and transfer in support of the Paris Agreement.

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Agnes cooking with an electric pressure cooker, Kenya. Image credit: CLASP/StoryxDesign




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Solving the clean cooking conundrum in Africa: technology options in support of SDG7 and the Paris Agreement on Climate Change

Abstract

We define and discuss the clean cooking conundrum in Africa, home to most of the world's population still reliant on polluting and unsustainable cooking technologies. We explore the technology options that meet both the competing needs of various SDG7 targets on energy access, including clean cooking and the challenge of achieving net zero carbon development. In doing so, we discuss the 'mutual neglect'[1] in the political economy of clean cooking, looking for realistic pathways aligned with NDC policy and planning for the Paris Agreement on Climate Change. Case studies reveal the significance of unintended or indirect benefits from technological innovation and growth in unrelated markets, for example the emergence of highly efficient Electric Pressure Cookers (EPCs) and the cost reductions in batteries driven by growth in the global electric vehicle markets, both of which has been a boon to the electric cooking sector in Africa. For higher-level policy discourse, we consider the windows of opportunity to create, steer and expand markets in Modern Energy Cooking Services (MECS) and the longer-term consequences this will have in terms of socio-technical lock-in and path dependency of government ambitions and policy choices.

[1] Newell et al (forthcoming) offer a political economy analysis of a 'mutal neglect' between electrification planning and clean cooking strategies, whereby modern energy planning has been disconnected from the planning for clean cooking.

The clean cooking conundrum

2.8 billion people cook with solid fuels[i], mostly firewood and charcoal, creating Household Air Pollution that causes premature death in 4 million people a year[ii]. This consumption is also a driver of localised deforestation and contributes 2% of global CO_2 emissions[iii] including short-lived climate forcing black carbon emissions. In total this leads to economic losses valued at $2.4 trillion per year[iv]. ESMAP have noted that while an additional 1.2 billion people since 2000 are now classified by the UN SDG tracking system as having access to 'clean cooking', there are in fact 4 billion people who do not have access to Modern Energy Cooking Services (MECS)[ibid]. Providing affordable access to MECS for this population is a socio-technical and political conundrum, made harder by the imperative to provide low-carbon technology options aligned with Nationally Determined Contributions (NDCs) to the Paris Agreement.

The divergence of SDG7

Sustainable Development Goal #7 includes targets on access to affordable, reliable, sustainable modern energy for all[v]. However, the challenge of clean cooking has been seen as a different sector from 'modern energy' (which became synonymous with electrification, infrastructure and distribution planning), and so SDG 7.1 was split in two targets. SDG 7.1.1 was set an indicator of "proportion of population with access to electricity", while 7.1.2 was set the indicator "proportion of population with primary reliance on clean fuels and technology"[vi]. 'Primary reliance' was taken as code for 'cooking' since the major energy consumption of households is for that daily task.

Thus begins a long debate about what is meant by clean cooking, clean fuels, clean technology, and indeed whether 'primary use' was a viable data point. The IEA report on progress towards SDG7 shorthand their reporting into 'access to electricity' and 'access to clean cooking'[vii]. Clean cooking is mostly defined as those having access to an 'improved cookstove' (ICS). In academic and grey literature, cookstoves are often classified in tiers, with biomass stoves according to their combustion efficiency and alternative fuels their emissions (HAP)[viii].

Until recently, field data collection was primarily based on national surveys asking questions about the primary fuel used for cooking (and heating) and the primary stove or appliance. This created various challenges. Firstly, it emerged that some ICS do not deliver health benefits, a recent systematic survey of research results shows the breadth of the problem[iv]. More importantly, the impact of the fuel and stoves is highly context-dependent. This led ESMAP to develop a new approach, which is now being rolled out in many countries – the Multi-Tier Framework (MTF)[x]. This looks at six variables that capture a context for cooking technologies and practices and creates a tier ranking across multiple variables, not just for the stove or fuel. For instance, cooking in a windowless shack is more problematic than cooking outdoors on a three stone fire. There is also the problem of stacking – many households use multiple stoves and fuels during the year, and partial but substantial use of a low-tiered stoves creates almost as many health problems as using the lower tier stove all the time[xi].

Stakeholders in the cooking sector also identify that the roll out of these ICS were not keeping up with population growth. While the Clean Cooking Alliance (CCA) cite that 400 million globally have gained access to clean energy over the last 10 years, the population of in sub-Saharan Africa (SSA) grew from 870m in 2010 to nearly 1.1bn in 2018. More specifically, the number of people without access to clean cooking across SSA grew from 710m in 2010 to 910m in 2018. In short, population growth is outstripping the current intervention strategies. Looking ahead, world population is expected to increase by 2b by 2050, the majority will be in countries that are currently using polluting and unsustainable cooking fuels[vii].

The challenge of net zero carbon

As climate change comes to the foreground of the world's attention, there is another layer of challenge to add to the clean cooking conundrum; how to achieve the rollout of net zero carbon cooking solutions? SDG7 includes the word sustainable in its description of modern energy, including targets that call for greater use of renewable energy (SDG7.2.), and greater use of energy efficiency (SDG7.3.). However, SDG7.2 has tended to be disassociated from indicator 7.1.2 which measures the proportion of population with primary reliance on clean fuels and technology. This has resulted in policies and projects that aim to provide households with higher-tiered stoves and fuels, to alleviate the effects on health and deforestation. Inevitably, this has led to an emphasis on the provision of Liquefied Petroleum Gas (LPG).

LPG is thought of as a relatively easily deployable, mature yet modern fuel that does not cause indoor household air pollution and is often a mitigation technology compared to the baseline scenario in many situations where solid biomass fuel consumption leads to a significant net increase in GHG emissions. However, LPG is a fossil fuel with the associated climate change implications and depicted as inherently unsustainable. As such, it receives general scepticism, if not outright ideological opposition, among western donors. That said, ESMAP's 2020[viii] report on the state of access to MECS presents its scenario for achieving universal MECS by 2030 as requiring 70% of Low and Middle Income Country households using LPG. Some argue that LPG is needed as a 'transition fuel' to fulfil SDG7 by 2030[xiv]. Even so, the exclusion of cooking from mainstream energy planning reveals climate policy contradictions and a disconnect in ambitions and technology scenarios, creating a potential rift in thinking among those focused on how to achieve the various targets of SDG7, without undermining the Paris Agreement on Climate Change.

It is clear cooking has significant climate and environmental impacts, though it is important to unpack the key numbers to better understand cause and effect. According to the UN's Emissions Gap Report for 2019, an estimated 400 million m3 of fuelwood is burned across Africa, per year, releasing over 760 million tons of CO_2e into the atmosphere[xv]. Overall, energy for cooking is calculated to contribute 2% of global CO_2[xvi]. In reality, there are places where the biomass regenerates soon after being extracted for cooking fuel. There are also places where there is a net loss of biomass, the so-called biomass hotspots[xvii]. Black carbon from residential solid fuel burning is estimated to add the equivalent of another 8–16 per cent of the global warming caused by CO_2.

The literature on net biomass losses and impacts from cooking barely discuss carbon capture per se. When a tree is cut, and the wood from the tree is burned (whether that be in a low or higher-tier biomass stove), the CO_2 is released from the biomass gathered above ground. However, CO_2 is also released from the decaying roots (and sometimes if it is wet ground, methane is released which is a more powerful climate forcer – this is particularly true when mangrove trees are converted into charcoal), and the world is deprived of the net-20 years of carbon capture by mature biomass.

Planting trees to overcome climate change is gaining momentum, and many schemes now offer carbon offset of industrial processes by offering to plant trees. But when a tree is planted, it takes 10 to 20 years to grow to the point where it significantly captures carbon (fast growing trees tend to be bad for the soil, and slow growing trees tend to capture less over a period of time). So retaining a mature tree means capturing significant carbon for the next 20 years. Allowing for a 60% loss of new seedlings, it takes 40 trees on average to capture the same carbon as one 30cm diameter mature tree, grown over a 20-year period. It is worth noting that the role of trees and biomass in sequestering carbon is complex[xviii], while avoiding the use of biomass for cooking will preserve mature trees, and should perhaps be in the toolbox marked 'nature based solutions' to climate change.

'Mutual neglect' in the political economy of clean cooking

Due to the disconnect between SDG7.1.1 and 7.1.2, and to some extent the disconnect between the SDG and the Paris agreements, we are only just beginning to talk about these things in the same room. Modern energy planning has been disconnected from the planning for clean cooking. Further, planning for clean cooking has been disconnected from climate change mitigation strategies.

Newell et al.call this a 'mutual neglect' in the political economy of cooking. They note that in 1893 the Chicago World Fair showcased a futuristic all-electric kitchen with an electric oven as the centrepiece. They go on to say that "not long ago the idea of electric cooking powered by on-grid or off-grid renewable electricity looked like a fanciful proposition for reasons to do with cost, poor grid connectivity and ingrained cultural and social attachments to cooking with biomass, especially in rural areas and among older generations. A series of technical and economic shifts have radically changed that landscape".

Until recently, the clean cooking sector barely discussed electricity, and the planning for electricity barely discussed cooking. Indeed, as recently as 2017, the IEA failed to discuss electric cooking as an option for lower-income households. However, soon after they claimed that "if we are to witness the kind of progress expected on electricity, clean cooking must be placed on a par with electricity access on the policy agenda, or better still, explicitly integrated with that agenda."[xx]

The CCA state that approximately 70 to 100 million dollars has been invested in clean cooking each year, globally, over the last 4 years. During the same period, Africa has seen an investment of $26 billion per year in electrification (approximately one third fossil fuel generation capacity, one third renewable energy technology, and one third transmission and distribution)[xxi]. In South East Asia, $34 billion has been invested in the electricity sector per year, $54 billion in India alone. This order of magnitude difference in finance and investment could be leveraged into clean cooking, helping drive a convergence with the electrification agenda.

The MTF has begun to collect more nuanced data and brought to the foreground the need for MECS, but it also illustrates this disconnect in thinking. The survey is applied in two modules, one which captures the access to electricity and one which captures cooking. The official diagnostic report[xxii] then presents these as two chapters, and the connection between the two modules is not shown. Researchers have used the data to make more connections[xxiii] but the very idea that the list of electrical appliances includes microwaves but not electric stoves, and that the cooking modules conflate LPG and electric cooking as a single variable, illustrates that each module seemed to be designed without due regard for the other module.

The consequences of this fragmented political economy of clean cooking, and the planning of electricity not being integrated with the possibilities of cooking, can be seen in countries such as India and Nepal. Nepal, one of the fastest electrifying countries in the world[xxiv], now wishes to pivot to electric cooking, and yet the wiring and transformers of their recent grid extensions are only sized for 300W – meaning that to encourage people to cook with electricity will require a second wave of upgrading the infrastructure, at least in rural areas[xxv].

It is true that most African countries lag behind in terms of household access to reliable electrical supplies, but this is likely to change in the coming decades, with increased effort to rollout both grid and off-grid solutions. If the planning for this is discussed in the same room as advocates for solving the cooking conundrum, then cooking loads can be taken into account. The capital cost of renewable energy technologies, principally solar PV and wind continue to decrease and more will be added to grid and off-grid across Africa. Auctions are reducing the cost dramatically, especially in Southern Africa, and concentrated solar power (CSP) stations are being built in Ethiopia at 4 cents/kWh[xxvi]. How can this new energy be leveraged to help solve the clean cooking conundrum for Africa?

A broad desire to overcome this mutual neglect, to harmonise plans for SDGs and net zero carbon, can be seen in a flow of recent calls to action and manifestos. Yet much remains to be done to create the political will to overcome policy contradictions and unlock the required levels of finance to solve the clean cooking conundrum. In the following sections, we look at some of the technological perspectives of electric cooking and discuss what can be done to rollout solutions, at scale, across Africa.

The importance of energy efficient cooking appliances

Until 2010, Zambia had a relatively low tariff and relatively strong electricity grid[xxvii, xxviii, xxix, xxx]. As such, consumers started to use electricity for cooking. The result was that 17% of urban households were reported to use only electricity for cooking with another 38% using it partially alongside charcoal, in 2010. However, the most common appliance was one used in 1950's USA – a large device with four hotplates, an oven and a grill. The result was that heating a pan was relatively inefficient, where the pan may or may not have fitted well with the heating element, and any imperfections in the bottom of the pan would result in heat losses, as well as heat lost up the side of the pan[xxxi].

This was all tolerable when the tariff was so low, and the supply of electricity reliable. However, in 2015 the tariff was raised across Zambia, and suddenly consumers felt the impact. It was now cheaper to cook with charcoal or LPG. The result was that many backed away from electric cooking, and the government set targets for the lower use of electricity for cooking, while increasing LPG consumption. How could this occur? How could people move away from clean cooking to either charcoal, which has health implications, or LPG, which has environmental implications[2]? It helps to pause on this line of thinking and look to another part of the world before coming back to this.

In Canada, around the same time, a company called Instapot was starting up. They developed the Electric Pressure Cooker (EPC), and while they were not the sole supplier, they nevertheless were the ones who popularised the technology in the USA. Chris Stevens the vice president of Instapot relates how in 2010 they were just four people in an office and if they sold a hundred Instapots, they were "over

[2] It should be noted that the grid emission factor for the Southern African Power Pool is relatively low, at 1 tCO_2/MWh in 2017, due to the high percentage of hydropower.

the moon"[xxxii]. He explains how 2015 was the hockey stick moment in their sales curve when they made sales of $100m, with 2016 yielding $200m and 2017 yielding $380m[xxxiii]. The timing of this story is important as automated energy efficient devices such as the electric pressure cooker did not really exist before 2010.

So how does the development of energy efficient electric pressure cooker (EPC) match up with the Zambia context? In short, when Zambian consumers were using electricity for cooking, they tended to use technology from the 1950's. Therefore, when the tariff went up, consumers pivoted away from devices that consumed excessive energy. In the meantime, the energy efficient devices began to be used in kitchens in developed economies, while they were not available in Zambia at the time of tariff rise. Now is the moment to bring these experiences together, in an act of policy continuity. Zambia continues to have relatively low tariff electricity, but this is likely to continue to rise, mainly to finance new grid infrastructure. Thus, there is a window of opportunity to rollout the use of highly efficient electric cooking appliances before high tariffs lead to a socio-technical lock-in of less sustainable cooking fuels. The promotion of energy efficient cooking could enable consumers to keep their electricity energy bills the same (or even reduce them), while continuing to use a clean and (mostly) renewable energy resource.

Diversity of appliances

The EPC has limitations and is not the only energy-efficiency electric cooking appliance that has emerged over the last decade. Others are also task-specific and have their own pros and cons. Induction stoves (or hotplates) are a flexible appliance, that offers a highly efficient transfer of heat from the stove to the pan, via magnetic resonance. However, some

The Electric Pressure Cooker (EPC)

Until recently the EPC was rarely advertised as an energy efficient appliance, rather it was promoted as convenient and time saving. Time saving because it both cooks food faster and can be left unsupervised. The pressurised environment is monitored, and heat is cut off while the pot remains at pressure. It is also convenient because as a one-pot meal it can be loaded in the morning and switched on with a timer to deliver freshly cooked food later in the day. The latest versions have Wi-Fi control built in so can be switched on remotely, befitting a modern urban lifestyle.

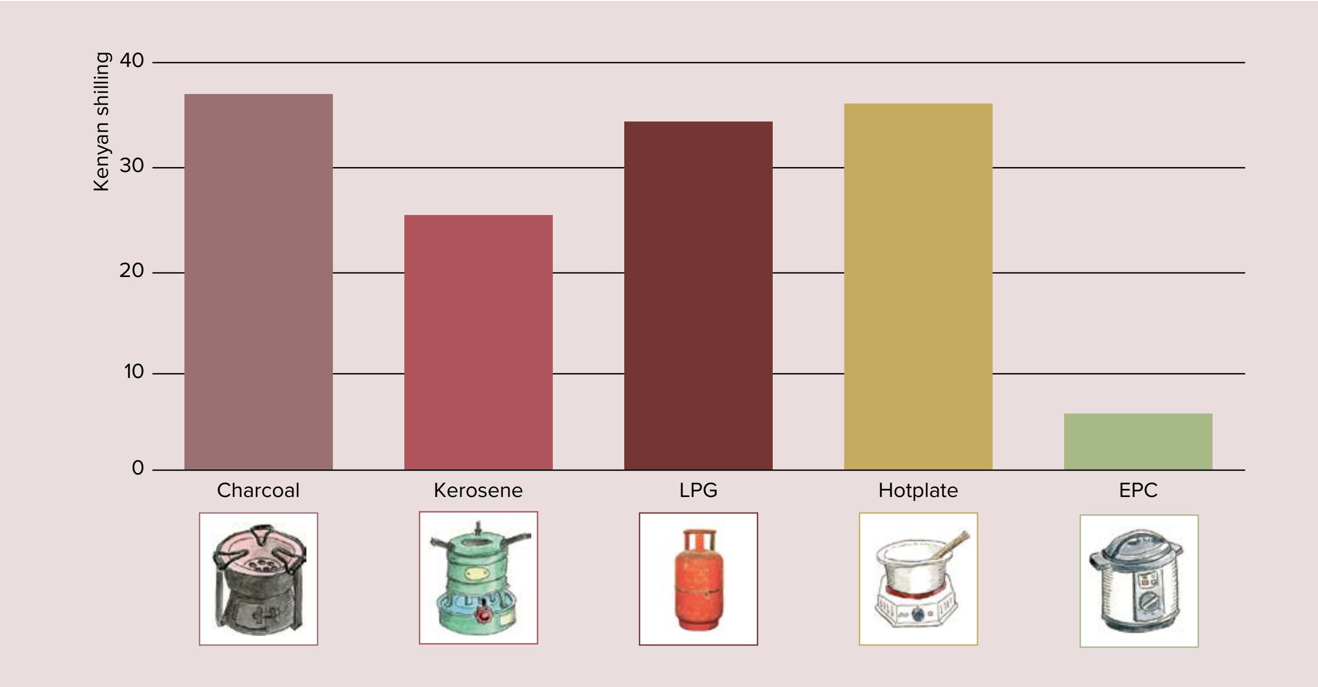
In 2015, UK researchers began to look at the EPC as an energy efficient device. They considered whether a good fitting pot, with a bottom that connected well to the heating element, would lead to an improved heat transfer. Further, it was tested to see if its simple air gap between pot and outer skin would slow radiant heat and retain heat for long simmering, and whether the strategic use of pressure could cook a meal in less time and with less energy. The answer was that an EPC, for certain meals, was indeed very energy efficient.

Immediately, the question of taste was raised. Can an EPC cook an everyday African meal to meet the expectation of local consumers? To answer this, a series of trials began in East Africa (and in SE Asia). Partners worked in Kenya, Tanzania and Zambia with real cooks, to test whether an EPC could cook meals to the taste satisfaction of consumers. They also showed the variety of meals that could be cooked, and they delivered both controlled energy tests and 'uncontrolled' energy consumption (i.e. after basic training, the cooks were left to cook in their own style and explore the devices). It was shown that the EPC delivers effective long pressurised cooking of beans, as well as enabling shallow fry and un-pressurised 'open lid' cooking.

The results were similar in every setting, with the EPC delivering an energy efficiency that is often headlined as one fifth of the energy consumed by a standard hotplate. In reality, it depends on what is being cooked. For short cooking such as frying an egg, there is marginal energy saving between a hotplate and an EPC. However, for 'long cooking' such as stewing beans (a staple food across much of Africa), the EPC can do this with a fraction of the energy used by a hotplate, and in urban settings mostly at a fraction of the cost of charcoal or LPG.

In 2020 the Global LEAP Awards Electric Pressure Cooker Competition attempted to identify high-quality, energy-efficient, and affordable EPCs that are appropriate for use in underserved markets. This includes areas with weak-grids and where grid connections are intermittent and of inconsistent quality, as well as areas where energy comes from off-grid systems such as standalone DC solar home systems and renewable mini or micro-grids (AC or DC). The data on EPC performance is now robust enough that the UK-funded MECS research project is often seen as being narrowly focused on this end-use application. MECS is much more than EPCs, but EPCs are a key tool in the clean cooking toolkit. In fact, they are doing for cooking what LED technology did for lighting, e.g. it is a game-changing technology that is highly efficient yet relatively affordable.

Figure 1. **Fuel cost of cooking 500g of yellow beans**



Source: Modern Energy Cooking Services (MECS), https://mecs.org.uk/

research disputes that this is as clear-cut as proponents of induction suggest.

Induction hotplates appear cheaper than EPCs, though the need for a set of steel pans bumps up the expense for household consumers[xxxiv]. It could be noted that an EPC comes with its own pot, something that is both a benefit and a limitation. Many cooks ask for a second pot, and if EPCs were supplied with an extra pot this would increase their flexibility in use.

Then there are ‘air fryers’. These would seem to be very task specific, but they are gaining considerable favour among African urban populations, and indeed in some countries are more widespread than the EPC. They too are very energy efficient since they effectively create a small fan driven oven. Fan ovens use about half the energy consumed by standard ovens, a fact that has led to significant energy efficiency gains in UK kitchens in recent decades. The UK now uses half the energy in its kitchens than it did in 1970[xxxv], due to a combination of energy efficient appliances (like the fan oven and induction hotplates), the greater use of pre-cooked food (e.g., frozen meals), and the reclassification of some data.

Kettles are of course quite ‘task specific’ in that they can only boil water. But it should be noted that boiling water is a large part of cooking processes, and kettles are very efficient (compared to boiling water in a pan on a hotplate). Indeed, among the middle class of Africa demand for kettles is on the rise. For example, over 30,000 kettles were imported into Kenya in the last six months of 2019[xxxvi]. Microwaves are also an efficient appliance, commonly used in developed economies, but generally for re-heating food rather than cooking from scratch. Data from cooking diaries in East Africa suggests that approximately 25% of meals are reheated food, and again we see that microwaves are being considered by the Kenyan middle class[xxxvii].

The key point is that there are now electric cooking appliance on the market that fit the way people cook and use a lot less energy than a standard hotplate. Data suggests that approx. 80% of common meals in East and Southern Africa can be cooked in an EPC. That is good news, but what does it mean for the remaining 20%? Should people have two devices? This sounds expensive, and when one compares it with the idea of a single charcoal fire can people be persuaded? Before we consider the issue of finance required by households to implement a transition to electric cooking, let us continue for a moment with a review of the last decade of technological change, as we look ahead to the next decade.

Electric vehicles and energy storage

One of the emerging shifts in global economies is the rise of electric vehicles. In the last 5 years, electric vehicles (and hybrids) have gone from a niche product to a common occurrence in developed economies. The pressure to reach net zero carbon in the transportation sector suggests that electric (and hydrogen) motive power is the solution, and that means developing new products and new infrastructure.[xxxviii]

In the same way that the emergence of electric cooking as a solution to the clean cooking conundrum may raise questions about the infrastructure of the African grids, so too the world is currently asking serious questions about its own grids[xxxix]. Can fast charging stations be rolled out in developed economies quick enough to meet the growing demand of electric vehicles? Can the range of vehicles be extended with new energy storage technologies?

The demand for energy storage has pushed the price of batteries down over the last decade, and continues to do so. When researchers working for the MECS project first considered the conundrum of electric cooking in Africa in 2013[xl, xli], lithium iron phosphate batteries were not available in the UK, and a 12V 100Ah (1.2kWh) battery cost £1600, at retail imported from USA. By 2019, such a battery could be purchased for £650 retail, and now in 2021, it can be obtained for £449 (with Bluetooth monitor). The simple point is that prices of energy storage are dropping dramatically.

The rapid electrification of the transportation sector has driven innovation in battery technology and new chemistries are coming on to the market. When the prospects of energy storage were assessed in 2015[xlii], the recommendation was that Lithium Titanate was perhaps the best chemistry since it had 20,000 cycles, no safety concerns, and was able to do rapid discharge (i.e. supply the higher power demands of cooking). At the time, titanate batteries were $2000 per KWh storage ex-factory. In 2021, they can be obtained for $200 per kWh ex-factory.

We also see the rise of energy storage modules for example the Tesla Powerwall[xliii] and the Moixa[xliv], among others. These devices have been designed for a developed economy market, and yet their development may hold merit for low and middle-income economies too. They mitigate weak grids and can maximise use of renewable energy. We shall discuss this further below, but for now we want to acknowledge that global momentum towards electric vehicles has lowered, and will continue to lower, the price of energy storage and improve the possibilities of electric cooking.

There is one other aspect about the electrification of transport that impacts African e-cooking. If all the vehicles in developed economies pivot to electric, then Africa will not have a supply of new or used cars based on fossil fuels, and possibly not be able to get regular supplies of petrol and diesel. IF the world reaches net zero carbon by 2050 a majority of African vehicles will also have to pivot to electric (or hydrogen), and that will 'force' an improved grid and off-grid infrastructure. It has been suggested that the transition to electric vehicles and greater use of renewables will prompt a more decentralised grid, where renewables are used in rural 'petrol stations' to recharge vehicles. If this becomes the solution, that would also assist the provision of domestic electricity inclusive of cooking. While developed economies struggle to upgrade old infrastructure to cope with the demands of electric vehicle charging, we may see emerging possibilities for a technological leapfrog across Africa.

The presence of electric vehicles, inclusive of their own ecosystem in low and middle-income economies, is already a reality. For example, Bangladesh has over 1.5 million electric rickshaws[xlv], based at the moment on lead acid chemistries with peak charging at 3am when the tricycles have finished their work for the day. This 'spontaneous' creation of a useable vehicle will likely be upgraded with reduced costs in energy storage chemistries, and the likelihood of it being replicated in other countries. Already electric bikes are gaining urban popularity, for example in Malawi tricycles with lithium titanate batteries are being piloted, charged by solar PV, using swappable batteries. There are similar examples for e-motorbikes in Rwanda, Kenya and Uganda where this form of transportation contributes significantly to daily mobility and commerce.

Grid electrification and urbanisation as key trends

So how can electric cooking be rolled out across Africa within the next 9 years? The first step is to recognise that Africa is increasingly urbanised and urbanising[xlvi]. By 2050, it is projected that there will be 2.5 billion more people living in cities compared to today, and 90% of this growth will take place across Asia (1.2 billion) and Africa (1 billion)[xlvii]. Urbanisation in the global South is said to have revealed "a new face of poverty, one in which urban communities cannot access or afford basic modern energy services for their development and empowerment".[xlviii]

In many urban centres, households are cooking with charcoal. It is important to note that a household using charcoal consumes approximately twice as much wood as a same sized household cooking with wood on a three stone (open) fire[xlix]. The process of carbonising the wood means that although charcoal is easier to burn and is more transportable and slightly more convenient than wood, the efficiency losses in the production process create a greater concentrated demand for wood than if wood itself was used for cooking.

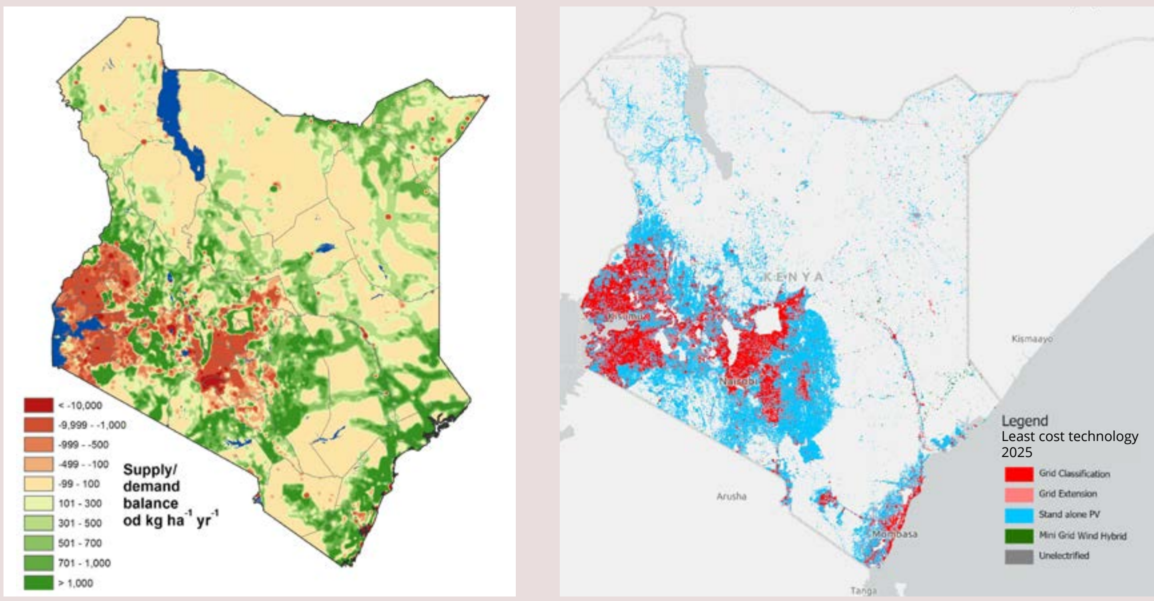
There are approximately 235m charcoal users in the world (and 2.2b wood users), accounting for 22% of global wood consumption for cooking fuel. However, what happens is that denser populations create biomass hotspots where the net biomass is rapidly reducing (while it is possible for woodfuel collection in remote areas to live in balance with their surroundings). While deforestation is often associated with conversion of forest to agriculture and that is the case in many contexts, the regular consumption of wood (in the form of charcoal) for cooking, creates hotspots even when the conversion to agriculture is discounted.[li]

Since deforestation caused by cooking is associated with dense populations, it should come as no surprise that it matches areas of electricity grid coverage. Consider for example figure 2 where the areas of net biomass reduction, shaded in red, overlap with the red dots of the grid coverage. So, where on-grid power generation is increasing, for instance in Uganda or Kenya, the possibilities of pivoting millions of urban dweller to electric cooking is a rapid possibility if all other factors such as affordability and cultural acceptance are in place.

Off-grid, mini-grid and emerging possibilities

Of course, not all of Africa is yet connected, and of the 780 million not yet in SDG 7.1 (access for all), the World Bank estimate that 500 million will be connected via mini grids[lii]. Solar mini grids in Africa have an uneven history. They are struggling with profitability, and there is a need to increase

Figure 2. Maps of Kenya indicating the overlaps between areas of unsustainable biomass consumption and electricity access



Kenya Non renewable biomass hotspots (2015)
Drigo et al. 2015[lxxix]

Potential least-cost technology distribution in Kenya by 2025.
Adapted from the Global Electrification Platform (2021)

the power demand on each mini grid, such that the operator can maintain revenues with a lower tariff. It could be noted that while the costs of solar PV and energy storage are reducing, a substantial portion of a mini grid cost is in the localised distribution (wiring, poles, etc.), and these are unlikely to come down substantially over the coming ten years[liii].

At the existing average tariff of a mini-grid, electric cooking is barely cost effective for household consumers[liv, lv, lvi]. This is partly the result of the high tariffs and, even with an energy efficient EPC, the electrical need, and partly the low cost of alternatives. Almost by definition, mini-grids are required in remote locations, and in such locations cooking fuels are often secured outside of the cash economy. They are more likely collected from nearby forests, thus collected biomass is therefore costed in terms of time not cash. This presents a barrier to technology switching, e.g., if the time is not valued (perhaps by the male of the household where the female is the collector) or cannot be used for income generating activities, then why spend 'real money' on electricity instead of time collecting fuel. Nevertheless there are emerging cases where cooking on mini-grids is being piloted and in some cases successfully[lvii], providing valuable proof of concept and learning to inform new projects.

Given the strong gender equity dimension to clean cooking, since the burden of collecting more often falls on women and children, there are compelling arguments for additional support for pivoting to MECS in low-income economies. For example, this can take the shape of Results Based Financing (RBF) for the mini grid operators or consumers. Or the provision of time-bound public subsidies to overcome capital barriers to clean technology uptake, as a means to unlock the longer-term non-financial benefits. We shall discuss this further below in 'mitigating capex' since it equally applies to off-grid home systems, and indeed even grid-based appliance acquisition.

Off-grid, home systems and emerging possibilities

A mini-grid demands a cluster of households, and if rural homes are dispersed the distribution infrastructure of a mini-grid doesn't make sense. There has therefore been substantial gains in solar home systems (SHS)[lviii], and the existing ecosystem is a mix of public and private sector delivery with various levels of support to kick-start and expand the market. SHS gained scale for lighting as an alternative to kerosene lamps, candles and expensive non-rechargeable batteries for torches. Their roll out coincided with the scaled use of highly efficient LED technology. It is perhaps worth noting that if solar home systems were dependent on incandescent bulbs, they would not be viable in the majority of contexts. Thus, it was the arrival of energy efficient appliances that enabled the growth of decentralised SHS technology, estimated to number 180m globally.

With the focus on low power lighting, the SHS market has pushed the boundaries of SHS by looking to other low power technologies. Phone charging has become ubiquitous, and low power TVs have become common. The SHS market utilised credit or Pay As You Go (PAYGO) technology, that enables households to space out their payments. By definition, users of SHS are quite dispersed and the sales or delivery infrastructure for these systems is a substantial portion of the overall cost. If one reduces a PAYGO system to cost per kWh, assuming a lifetime of ten years (limited mainly by battery life) some systems can be calculated as high as $2 per kWh[lix].

At such a cost higher power activities such as cooling, cooking and irrigation appear beyond the capabilities of a SHS. However, as discussed both solar PV and energy storage continue to drop in price, and therefore higher power SHS are being piloted and introduced into low-income markets. For example, Sunculture offer a "rainmaker" irrigation pump system with 310W panel at $1000 or $42 a month. The SHS industry is demonstrating that consumers can start with a lower powered system and can then upgrade when they are ready. Customer acquisition, particularly for remote areas, is an expensive component of distributing these products, and is almost the same whether someone signs up for a low power lighting SHS or a higher power irrigation or cooking system. Kachione in Malawi is leveraging its acquisition of customers on its lighting sales to offer an upgrade to a 300W system for cooking with a bespoke EPC, supplied through community women's groups. They estimate their system will cost $300 to upgrade from a lights only system[lx]. However, we must be cautious in our hopes. If households feel they do not pay for their fuel (by collecting it or using agricultural waste), they as a whole family, and their male leadership in particular, will likely be reluctant to substitute family time with regular monetary payments to an outside company.

Several groups are also exploring systems without batteries – either thermal batteries, phase change batteries or no energy storage. While solar box or concentrator cooking have always been limited by the need for the chef to operate the device in the sun, a direct solar electric system could be used during the day within the house. Since electric pressure cookers with their insulation can keep the food hot, this is another option[lxi]. Technological success will increasingly be determined by the business model rather than the hardware itself, and in this regard a solar home system capable of cooking will conceivably become cost effective in some contexts.

Given the advent of Lithium Titanate batteries (and the reducing cost of lithium Iron Phosphate batteries), it is possible that a SHS could be designed to last 20 years – although the EPC would likely need replacing after 5 years. Leach et al. have produced a model of such systems and the equivalent levelised cost of energy (LCOE) kWh cost is equivalent to grid tariffs. Given that some national energy regulators allocate up to $3000 per connection for grid supply to rural areas, this investment could instead be used to provide families with a robust SHS, that could include cooking appliances.

Displacement settings

Before moving on to look at ways of mitigating the capital expenditure of households for electrical cooking appliances, subscriptions and systems, we should briefly consider the many countries that host forcibly displaced populations. This is because they constitute a significant and growing population, especially across Africa, and have a demographic profile and status that lends itself to the introduction of cleaner energy technologies that can trigger positive spill-over effects for local host communities[lxii].

The number of forcefully displaced persons has doubled since 2010 to more than 80m, over 1% of the world's population, and is a trend likely to continue[lxiii]. 85% of all refugees are hosted in the Global South, more than 30% in Africa, where the average age of a refugee settlement is almost 20 years[lxiv]. In response, there is a consensus on the need for longer-term and development-oriented solutions to the local and global environmental problems that are both a cause and effect of forced migration. This is aligned with the Global Compact on Refugees (2018), which calls for actions to 1) help ease pressures on host countries and 2) enhance refugee self-reliance[lxv].

Fuel poverty among displaced 'persons of concern' often leads to unsustainable deforestation and a range of risks to human life and health, including household air pollution, conflict with local communities and violent crimes committed against the refugee women and children who walk to harvest woodfuel[lxvi]. The lack of access to reliable electricity supresses opportunities for education and income generating activities for families, and can undermine the ability of humanitarian organisations to deliver essential services. The critical role of energy became clear in 2020 as part of UN's global COVID-19 Humanitarian Response[lxvii].

Despite these clear issues and opportunities, access to sustainable energy has traditionally been overlooked or neglected within the humanitarian agenda because of a lack of expertise and funding, or a reluctance from host governments to authorize long-term infrastructure in 'temporary' settlements. Research into these issues was first conducted by the Moving Energy Initiative (2015-2020) and it is now known that on average just over 70% of the total energy spending of displaced and host community households goes to cooking[lxviii].

Research conducted by UNEP DTU and UNHCR in Tanzania in 2017 revealed strong latent market demand for LPG among refugees, as a cleaner, safer and low-carbon option compared to the baseline scenario of unsustainable charcoal and woodfuel consumption. This led to a 3.4m USD market creation plan and funding proposal submitted by the Global LPG Partnership in 2020, endorsed by UNHCR and the Government of Tanzania. The project aims to provide time-bound subsidies to supply 88,000 refugees and 40,000 host community members as a means to overcome the capital barriers to market entry. Similar projects could be designed for the rollout of solar e-cooking, where the circumstances are conducive.

Once again, this issue also has a strong urban dimension. An estimated 2 out of 3 Internally Displaced Persons (IDPs) and 60% of refugees live in urban or semi-urban areas (2019). As above, depending on the infrastructure of the country, displaced communities living in urban and peri-urban settings often have access grid infrastructure. They could in theory draw on this to access services, although it is the social inclusion or lack thereof that tends to isolate them and lead them to being inadequately serviced. Informal settlements combined with a lack of awareness of the options and limited household budgets for up front capital combine to result in poor energy access.

For the 60% urban or peri-urban displaced, the opportunities mentioned above in terms of leveraging electricity infrastructure could be applied. For the 40% rural, solar PV mini-grids and SHS are a viable option, and have perhaps greater merit because humanitarian organisations could offer the upfront capex, switching their own power supply from mostly diesel generators to offer an anchor load. While there is huge and largely untapped potential in this space, it is politically more complicated than designing solutions in the 'normal economy'. That said, UNHCR and other humanitarian agencies now see the need for accessing global sources of development and climate finance in order to deliver their own sustainability strategies, and the ambitions of progressive countries hosting displaced persons such as Ethiopia, Kenya, Rwanda, Uganda and Zambia. This includes energy (SDG7), prioritised at the Global Refugee Forum in Dec. 2019 where the High Commissioner for Refugees launched the 'Clean Energy Challenge' that calls for a multi-stakeholder and development-oriented approach[lxix].

Cost effectiveness and affordability

Until recently, electric cooking was thought of as too expensive for developing economies. However, with the rise in charcoal prices, the current price of LPG, and the efficiency gains of new appliances, the game is changing. A key document 'Cooking with Electricity – a cost perspective'[lxx] is one of a number of emerging analyses that makes clear that electricity in many contexts is now cost effective. Through five case studies the report illustrates the range of costs and trends based on field data to indicate that in certain contexts electricity, whether on-grid, mini-grid or SHS, is already comparable with, at a lower cost, than alternative fuels.

Mitigating capex

These technological hopes for Africa, like so many solutions, depend on political will and upfront capital expenditure (capex). This is true even for fossil fuel generation of electricity, but generally more so for renewable energy generation technologies. As discussed briefly above, the LCOE of renewable energy technologies is becoming cheaper and projects more profitable, leading to considerable investment, at a large scale, so to some extent electricity infrastructure will continue to evolve. Given the growing political will to work towards net zero carbon, we can have a reasonable hope that governments commit to their NDCs, where low-carbon energy infrastructure is high on most agendas. However, for non-grid solutions, capex financing and end-user affordability are closely connected, where households connected to mini-grids need to find $50 to $100 for a single cooking appliance with appropriate pans, while off-grid SHS need to find $300 to $900.

The simplest way to spread out such costs is through credit. A wide array of micro credit options exist for communities, but to date they have barely recognised that modern energy cooking appliances are a worthwhile investment. Professionals talk about productive use devices, and many micro-credit providers require participants to explain how their loan will increase their revenue. If the appliance could save the household expenditure then surely it should be eligible as a legitimate use of a loan[lxxi].

PAYGO options are a feature of the solar home systems and are gaining ground for the use of LPG. Operating effectively as a service, the household has the equipment installed by the operator, and its use is monitored by data flows. Where mobile money exists it can alleviate the need to physically go to an agent or bank to make payments. Offering PAYGO kitchen appliance is just starting with ATEC in Asia offering a PAYGO induction stove[lxxii], Okra offering a PAYGO SHS with cooking appliances[lxxiii], and a producer of EPCs is about to launch a PAYGO service. However, PAYGO only spreads payments, it doesn't necessarily reduce the overall capex. In fact, since most credit or PAYGO offerings need to cover the cost of financing, the charges often total more than the cash purchase price of the appliance or system. However, there is the potential to leverage RBF and Carbon credits to offset some of the capex, if the non-financial benefits of the technology can be measured and verified. The World Bank Clean Cooking Fund ($500m) is already utilising RBF as its main project financing mechanism, incorporating the monetary value of the environment, health and to gender equity co-benefits, converting these into cost savings which are then passed on to the consumer[lxxiv].

Similarly, carbon credit has a promising role to support clean cooking project investments, offsetting the capex to consumers. In the past, carbon credits on improved cookstoves faced verification challenges, as a representative of the scheme needs to physically check whether the ICS is in constant use or whether the household purchased but didn't use it. In contrast, electric cooking opens up the possibility for metered verification, a relatively easy and cost-effective means to verify real-world consumption, which can be shared remotely through mobile networks.

What about other forms of modern energy?

In this article, we have mostly focused on electricity as the main expression of "modern energy". This is partly because SDG7.1 has become synonymous with electricity provision, but it is a means to confront the idea that there has been a mutual neglect of considering electricity for cooking, and that leveraging investments in electricity for cooking could make a significant impact, relatively quickly. It also addresses the pivot to net zero carbon as it builds on the back of transforming electric networks to low carbon, combined with the rise in affordable off-grid renewable energy technologies.

That said, there is no single solution or silver technological bullet to the clean cooking conundrum. Cooking is a central part of the busy and evolving social lives of households in a complex world, so no one solution will fit all contexts. Some donors talk of LPG as a means to reach SDG7.2 on the basis that it is a 'transition fuel'[lxxv], while other dismiss it on principle as a fossil fuel.

However, the idea of transition suggests that we cannot wait for the electricity sector to provide affordable and reliable power for cooking, and that LPG is a flexible infrastructure that could be set up in a few years, and then presumably dismantled when other options are viable. There are two key challenges to this view. The first is finance: why spend on LPG or ethanol distribution infrastructure when you could spend on electricity? Most LPG requires some form of subsidy to be affordable for the poor. India currently spends $5 billion each year on LPG subsidies, funding which would facilitate a significant purchase of EPCs at a reduced cost. And this is not the cost of setting up the infrastructure, it's just the annual subsidy. Setting up the infrastructure means shipping, agents, distributors, charging stations etc. If African countries spend their money on LPG, it will take away finance from electrification. These considerations have long-term consequences in terms of socio-technical lock-in and path dependency and should be considered carefully in national energy policy and planning, especially in the light of the NDCs and the low-carbon imperative. However, there is a compelling case for a 'special exemption' for the humanitarian sector, where the energy needs of forcibly displaced persons justifies the rapid deployment of LPG as the best solution to address the needs of large and densely populated informal settlements e.g. those that emerged as a result of the Rohingya refugee crisis in Bangladesh in 2017.

One of the mitigating factors when considering whether to pursue LPG as a transition fuel is the possibility of it pivoting to a low carbon solution. A recent report on bioLPG illustrated how municipal waste could be used to generate bioLPG[lxxvi]. Municipal waste gases can be used in other technologies (and will need to be used) but the possibility of bioLPG at least challenges the dismissive voice of the anti-fossil fuel lobbyists. Similarly, some proponents see biogas, ethanol and liquid biofuels as possibilities however there are currently challenges in terms of supply and distribution.

Conclusion

There seems to be an emerging moment of change, regarding clean cooking technologies. Past difficulties in separating electricity access and clean cooking are being brought to the foreground, and there are increasing calls for integrated energy planning. 2021 has seen a flurry of international discussion on this with calls to action and high-level dialogues. While this is still focused on the Sustainable Development Goals, it comes at a time when climate change is also coming to the foreground of thinking and planning, at all levels. In this context, the High Level Dialogue on Energy working group 1 suggests five principles that should underpin an energy access shift[lxxvii]; the first one is to "prioritize political commitments and financing, with cooking energy demand fully integrated into energy planning and strategy development". A set of partners led by the Africa-Europe Foundation makes the case to "integrate clean cooking into NDCs and national energy planning"[lxxviii]. Ultimately, overcoming the 'mutual neglect' discussed in this article is a necessary step to making a low-carbon technological leap in cooking with energy efficient appliances.

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Scaling SME Financing for Climate Technology Transfer in Least Developed Countries

Abstract

The availability of, and access to, financing is recognized as a critical driver of technology transfer in the area of climate technology and clean energy financing, leading in recent years to the mobilization of new pools of public funding and expansion of existing donor-led financing facilities across a range of development sectors. This increase in funding pools has stimulated growth of commercial financing in the private sector, leveraged by financial innovation, enabling some technologies to move into the mainstream, driven by technical innovation, scale and falling technology costs. Despite these trends, the amount of financing reaching small and medium enterprises (SMEs) in the least developed countries continues to be insufficient for projects and businesses that often offer the kinds of technology and business model innovations that hold greatest potential to promote climate action and mitigation and / or build resilience and adapt preemptively. In this article, we use examples of projects that we have worked with to illustrate and explore the challenges of raising finance as an SME project developer, and how, over the last decade and half, various players in the financial ecosystem have been working to develop solutions to meet this challenge.

What is the Core Problem?

The availability of, and access to, financing are consistently recognized as critical drivers of technology transfer in the area of climate technology and clean energy financing. Recognition of this fact has led in recent years to the mobilization of significant new pools of public funding as well as the reinforcement and expansion of existing donor-led financing facilities across a range of development sectors (e.g., clean energy and cleantech, environmental infrastructure, climate adaptation and resilience initiatives).

This increase in funding pools for climate tech and clean energy has in turn stimulated growth of commercial financing in the private sector, leveraged by financial innovation in structuring "blended" approaches and mechanisms.[1] As a result, some technologies in a number of countries and regions have moved into the mainstream, greatly facilitated by increasingly competitive costs (as measured by the levelized cost of energy), and driven by technical innovation, scale and falling technology costs. Solar PV and onshore wind being cases in point, with the cost of solar PV falling by 83% and the cost of onshore wind falling by 39% over the period 2010 to 2020.[2] And with the construction of a 2 GW solar power plant in Abu Dhabi in 2020, the delivered cost of solar power reached its lowest level ever, at just US cents 1.35 per kWh.[3]

Despite these positive trends, the amount of financing reaching small and medium enterprises (SMEs) in the least developed countries continues to be insufficient. For example, the International Finance Corporation (IFC) estimates that 65 million firms, or 40% of formal micro, small and medium enterprises (MSMEs) in developing countries, have an unmet financing need of $5.2 trillion every year. Of this, East Asia and Pacific accounts for the largest share (46%) of the total global finance gap, followed by Latin America and the Caribbean (23%) and Europe and Central Asia (15%).[4]

By contrast, larger companies and projects are able to mitigate their risks adequately to secure finance; smaller projects and companies, proposing emerging solutions are much less able to attract finance: questions of scale, issues of market creation, heightened perceptions of technology and business model risks, regulatory environments, lack of liquidity all play a role.

Yet it is these SME projects and businesses that often offer the kinds of technology and business model innovations that hold greatest potential to support climate action and mitigation and / or build resilience and adapt preemptively. The business models developed by PFAN supported projects **Inspira Farms**, **Koolboks** and **Sokofresh** (see case studies in text box 2) are all good illustrations of this trend, whereby technology, in these cases in the cooling / cold chain sector, is harnessed to address a previously unmet need and create new business verticals and services.

Admittedly, there are vast sums of finance looking for investment opportunities in these frontier markets[5], and blended finance solutions[6] have begun paving a new path, but the millions to billions transition is yet to be realized, let alone the required trillions. IEA estimates that spending on clean energy technologies and energy efficiency will need to reach around USD 600 billion in annual capital spending by 2030 in its Sustainable Development Scenario, and more than USD 1 trillion in its Net Zero by 2050 Scenario. [7]

In this article we explore the challenges of raising finance as an SME project developer, and how, over the last decade and half, various players in the financial eco system have been working to develop solutions to meet this challenge.

Lessons Learned Working with SME Project Developers

The authors have been working over the past 15 years with climate mitigation – and to a lesser extent climate adaptation – projects in Asia, Africa, and Central and Latin America. Most of our efforts have been spent on identifying promising projects, and providing targeted coaching assistance to the project developers, with the aim to help them improve

[1] According to Convergence, a global network for blended, finance, "Blended finance is the use of catalytic capital from public or philanthropic sources to increase private sector investment in sustainable development. Blended finance has mobilized approximately $140 billion to-date based on Convergence data." See https://www.convergence.finance.

[2] https://www.weforum.org/agenda/2020/11/cost-renewable-energy-falling-race-to-zero-emissions/

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[5] As much as $35 trillion of investments will be required globally to expand renewable energy capacity over the next decade – an amount equivalent to a third of current assets of the global fund-management industry. See "How Green Bottlenecks Threaten the Clean Energy Business." Economist. 12 June 2021. https://www.economist.com/leaders/2021/06/12/how-green-bottlenecks-threaten-the-clean-energy-business

[6] A blended finance approach, using concessional capital, can address the challenges and risks associated with project finance. An excellent resource on blended finance is the website of Convergence, which tracks and helps to facilitate deals by linking diverse sets of investors with potential projects (www.convergence.finance).

[7] See IEA. 2021. *Financing Clean Energy Transitions in Emerging and Developing Economies*. Special Report in collaboration with the World Bank and the World Economic Forum. P. 26.

their business models and plans and raise investment for their businesses.

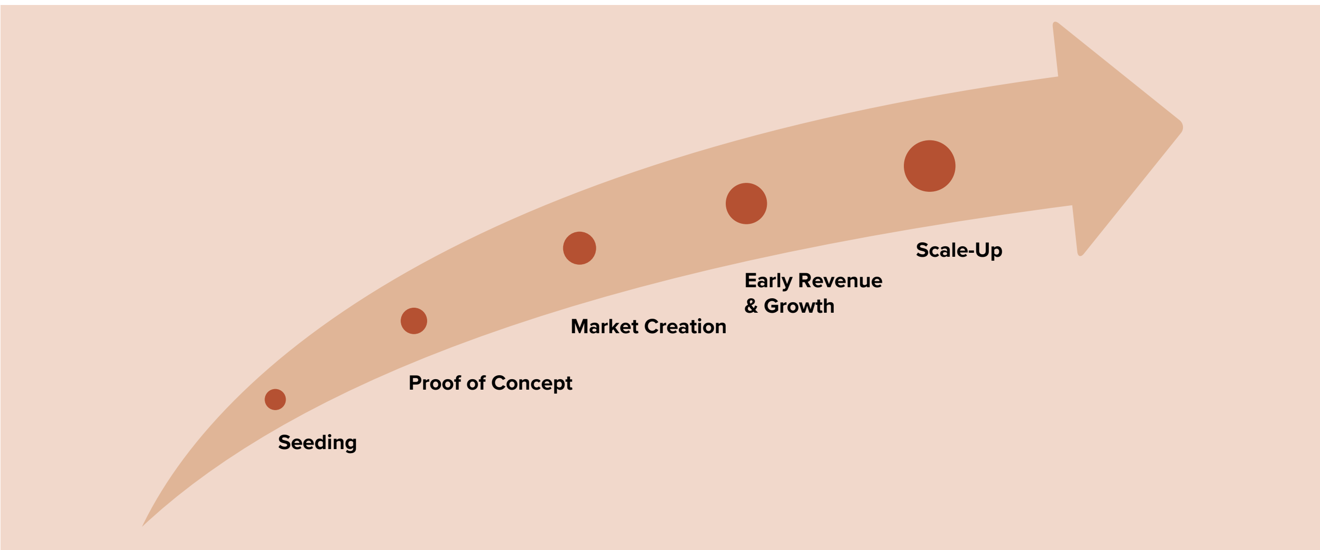
In our experience there are broadly 2 types of business development approaches in the clean energy space: an infrastructure approach where an independent power producer (IPP) seeks to establish a clean generation capacity (solar, wind, hydro, biomass, etc) for grid or captive offtake under a power purchase agreement (PPA) – **IPP Infrastructure Approach** (the case study on the **Thulo Khola Hydropower** project in text box 2 is a case in point); a business to business (B2B) or business to customer (B2C) distribution of energy products or services through a **distributed energy approach**, with development facilitated by distributed energy services companies (**DESCO Approach**). Distributed Energy Approaches are most often associated with energy access and climate action solutions eg for the distribution of solar home systems and energy appliances or improved cook stoves, mini- and microgrid operators / distribution of water, waste and sanitation services etc. The case studies on **Vitalite** and **ATEC** in text box 2 provide good examples of the DESCO Approach.

The key commercial and financial risks of the IPP Approach are embedded in the PPA and the creditworthiness and reliability of the off-taker and the agreed tariff level. In simplistic terms, once the PPA and tariff are agreed the main risks revolve around development, technology, construction and commissioning, which costs can likewise be projected and managed with some certainty. The development path from concept through pre-feasibility, feasibility to implementation and operation is clear and relatively linear and there are well understood and established processes, techniques, and financial instruments to help de-risk projects and manage residual risks (construction guarantees / payment guarantees / cash sweep to create debt service reserves / tariff indexing / take or pay clauses / priority dispatch / political risk guarantees etc.). Because of the supposedly steady and relatively predictable cash-flow this type of asset produces, it lends itself well to structured and project (limited recourse) finance techniques providing the deal size is reasonable (> USD 10 million). Because of their linear nature, it is also usually possible to calculate the time horizon and required financing runway for these sorts of projects, albeit such plans, especially in many developing countries, are still exposed to regulatory, bureaucratic, and political risks.

Development and implementation of DESCO Approaches are a lot less predictable. Companies typically need to navigate the phases shown in Figure 1 below.

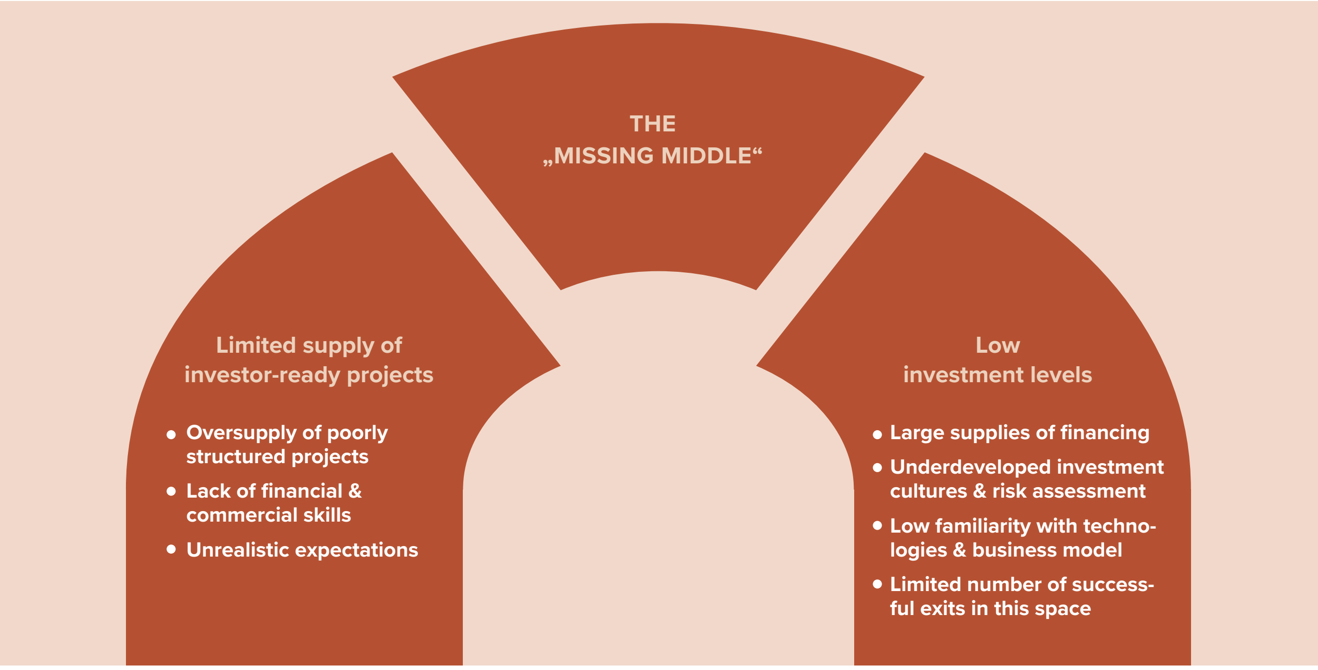
Progress through these phases is erratic and rarely linear with small and big advances being met with frequent setbacks and learnings which need to be integrated into the business model and planning. One of the main challenges is having enough and reliable / meaningful data (eg on costs / tariffs / customer numbers and behaviour / affordability / price sensitivity etc.) on which to be able to manage and

Figure 1. Typical Growth Path for a Start-up Company



This progression applies to start-ups in energy sector, and is typical of the challenges faced by DESCOs in developing markets.

Figure 2. The Missing Middle



The chart shows the significant gap between the developers of climate and clean energy projects and investors who have capital and are seeking profitable investments into such projects. (Source: PFAN, www.pfan.net) (Source: UNIDO)

price risk and base investment and financing decisions. It is difficult to predict the time horizon or calculate the required financial runway to achieve key milestones (positive cash-flow / profitability etc).

Both IPP and DESCO Approaches face the same fundamental challenge of raising finance and over the years we have provided support to both sorts of project – IPPs and DESCOs, but they require quite different strategies for dealing with the project development and raising of financing. Over the past 3 – 5 years the proportion of DESCO companies and projects that we work has risen to now comprise a majority of our portfolio / activity (ca 60% DESCO; 40% IPP), underlining the additional challenges facing DESCO type projects and companies. For this reason, we propose to focus our attention predominantly on the SME DESCO sector for the rest of this article.

The Core Challenge: The Missing Middle

As Figure 2 shows, there is a major gap between developers of climate and clean energy projects on the one hand and investors on the other.[8] Project developers have identified opportunities and are promoting specific projects, but often lack financial and commercial skills. On the other hand, investors who have funds to invest, often have difficulties sourcing and identifying well-developed, bankable project proposals.

The main cause of the missing middle is an experience gap, as well as a language gap. In terms of experience, project developers generally lack commercial and financial skills and do not have an understanding of different ways to structure investments into their project and to explain that to investors. For their part, investors often have limited familiarity with many of the climate and clean energy technologies and business models, and do not have well established channels and sufficient resources to identify and vet, assess and prepare (i.e. to "originate") projects for investment. In addition, investors are concerned about the still limited number of exit opportunities in the SME climate and clean energy space, and this increases the perceived investment risks into these types of companies (see also the *Exit Challenge* below).[9] As

8 This gap is described in "How Green Bottlenecks Threaten the Clean Energy Business." Economist. 12 June 2021.

9 In general, the markets where clean energy and climate projects operate in developing countries are relatively small and illiquid, which means that buyers and sellers are few and far between. This means that initial investors in such projects who want to sell their shares in the project to other investors often face difficulties in making an "exit" and recouping their investment and whatever gains they may have on paper.

a result, there is a divergence of expectation and assessment around project maturity and readiness, valuation and risk levels, which frustrates constructive developer – investment engagement.

Importance of a Mentoring & Transaction Management Approach

In our experience, it has been possible to overcome the missing middle gap through a highly focused approach that relies on the assignment of transaction advisors (coaches) to work with SME project developers. The coaches can be assigned to work with project developers over a period ranging from a few months to a year or longer, in order to help the SMEs pitch their projects and raise the needed investment. A focused mentoring approach can help SMEs to overcome challenges in four key areas: clear identification of target customers and resulting revenue streams, development of an operational and scalable business model, design of a coherent investment structure and the ability to communicate with investors.[10]

First, many project developers focus on the application of a technology to solve a particular problem (e.g., solar-powered irrigation) but do not pay enough attention to understanding market forces, identifying customers, and developing a business model to apply and scale up the technology among a group of commercial customers. In our work with SME project developers over the past 15 years, a common initial sticking point is to clearly identify their market segment and develop a cost-effective approach for customer acquisition.

Second, a common weakness in many early-stage business plans that we have reviewed is the lack of a clear operational plan for delivering the products and services to the customers they have identified using a clean / climate technology as a delivery channel. The key to being able to effectively tap into a market is to design an operational model that addresses a specific market segment, and that can be consistently delivered and scaled up to deliver value for commercial customers.

Third, SMEs often lack the sophistication, experience, or knowledge to be able to raise funds on their own. Many developers focus on identifying target investors or lenders (the "who") before they have successfully developed a compelling investment case (the "what"). In practice, successful fundraising involves assessing, understanding, mitigating and pricing risk, while also polishing the business plans and investor pitches to help them improve the probability of raising funding. The process involves detailed review and work on business plans, financial projections, and investor presentations, with a focus on gathering and marshalling compelling and reliable data and identifying and filling gaps. It is only after these steps have been taken that it makes sense to "pitch" projects to investors whose interests, investment appetite and return expectations are aligned with the project being offered by the project developer. Without this we often see businesses pitching to the "wrong" sort of investors whose interests are not aligned with the returns and development benefits which the business offers or presenting their project too soon as investor ready when there isn't enough data to back-up the value proposition.

Resolution of these challenges enables new business models to emerge as demonstrated by companies such as **Koolboks**, **Sokofresh** and **Solshare** (see the case studies in text box 2).

Key Scale-up Challenges

As companies move through early-stage growth to scale (see case study on **Ather Energy** below) some of the specific challenges they face include:

- basic R&D to develop the business opportunity and to address the uncertainty and risk faced by companies in commercial markets;
- identification of paying customers and development of distribution channels which are capable of reaching them in cost effective way;
- development of tariffs, pricing models and cash collection systems which correspond to the payment ability and readiness of the customer base;
- development and implementation of robust standard operating procedures;
- balancing the need to prove the business model to be able to attract funds to move to scale against the need to scale quickly to gain critical mass and operational profitability;
- introduction of appropriate management and governance structures to meet investment standards and requirements;
- costs for software and systems which often need to be developed as proprietary;

[10] PFAN currently has more than 160 advisors supporting SME project developers across its regional networks in Asia, the Pacific, Africa, and Central America. The advisors are established and experienced in their individual local markets, entrepreneurs respect the insights and experience gained that the advisors can provide across different geographies. Other similar programs such as Get.Invest also use a similar coaching model (see text box 1).

- costs of managing international procurement and trade, protection of IP rights;
- availability (and retention) of skilled staff – lack of education, training and qualifications;
- lack of clarity and predictability of regulatory and legal frameworks;
- limited practical cooperation among businesses, governmental and non-governmental organizations, donor-funded initiatives, and academic institutions working in the area of climate and clean energy (though this is an area now receiving increased development attention eg through the Zambian Off-grid Energy Task Force in connection with the Swedish Power Africa Beyond the Grid Fund for Zambia initiative).

Managing Risk

A project becomes more attractive as the project risks are minimized. In our review of thousands of business plans, we have found that the avoidance of discussion, or lack of a realistic assessment of risks, is a common blind spot. The major risks that SME DESCO developers face usually include market risks, credit risks (on their customers who are perhaps paying on a PAYG basis), currency risks (because their funding is in USD and their revenue in local currency), liquidity risks and operational risks. Increasingly, in a post-Covid world, investors are also looking for enhanced resilience to external shocks and the ability to manage uncertainty. Climate risk is an exponential factor for any company operating in the upstream / downstream agricultural space (farm inputs / market aggregation / cooling and processing / cold chain & storage etc).

It is important for advisors working with SMEs to actively seek to identify these project risks and work with developers to either avoid, mitigate, transfer or finally accept these risks. Risks that cannot be avoided can be covered by various types of insurance that may be available (e.g., political risk, currency risk hedging, performance bonds and guarantees etc.). A strong process for identifying and mitigating risks in a business plan increases the probability of funding. Another benefit is that during the process of risk assessment, project developers review a range of risk scenarios, and this often leads them to modify their technology selection or business model, and even in some cases to decide not to proceed with a project.

Part of the challenge in identifying and managing risk, as alluded above, is the lack of reliable data in meaningful quantities. This often leads to the need for extensive testing and piloting at small scale before investors can be convinced to commit more fully. This in turn leads to longer lead and development times and the requirement for longer financing runways for DESCOs before they get to commercial financial close, thereby putting additional financial strain on the developers and sometimes leading to funds simply running out.

The Exit Challenge

The ability to arrange a successful financial exit is a critical component in building the type of robust capital market needed to support continued innovation and scale-up. In the climate and clean energy space, especially for smaller projects with investment sizes less than $10 million, the lack of successful exits is a real problem for investors. To take just one sector, distributed clean energy generators have the advantage of improving the resilience of the grid and reducing or downsizing the need for transmission infrastructure. Such decentralized energy systems are an increasingly important alternative, or complement, to utility-based grid power. However, they face a significant challenge in finding a financial exit for investors after the initial investment phase.

In general, we have not seen many successful exits in small and mid-size climate and clean energy projects. In more developed off-grid energy markets like East Africa, the lack of exits often keeps later-stage commercial investors – who seek evidence of exits as proof points – on the sidelines. These later-stage investors are the key to providing companies with the capital they need to reach scale, expand into new markets and ultimately serve more off-grid customers. Below we share a few examples of exits that may point to a way forward for investors in SME climate and clean energy projects.

Secondary sale of shares. One recent notable exit in the off-grid energy space was Acumen's exit from Orb Energy. Orb was initiated in 2006 and provides collateral-free loans for rooftop solar systems for SMEs in India. Acumen made an initial investment in Orb in 2011, and exited its investment in 2020 through secondary sale of its shares to other investors. During its nine-year investment period, Orb was able to raise $25 million of follow-up investments from other investors and sales of its solar rooftop systems increase more

TEXT BOX 1: The Role of PFAN and Similar Advisory Programs

About PFAN
The Private Financing Advisory Network (PFAN) was initiated in 2006 as a mechanism for taking practical action to address the SME financing gap mentioned in the main article. The activities of PFAN focus on a specific niche: the Missing Middle.

From a modest start identifying initial sets of projects in Latin America and then Asia during the period 2006-2009, PFAN has grown into a global network of more than 160 climate, clean energy, and finance experts, who are managing advisory services to a pipeline of more than 300 projects spanning Asia, Africa, Central America and the Caribbean, and the Asia-Pacific region. The basic PFAN advisory services include the following:

- Professional coaching and advice on project development and preparation, provided at no cost to entrepreneurs;
- Matchmaking, introduction to investors and investment facilitation;
- a fixed fee for advisers;
- potential for a success fee when the project shifts from initial development coaching to investment facilitation; and
- inclusion through the PFAN network in a series of skill-building and investment facilitation workshops, aimed at building a pool of investor-friendly projects for consideration by equity and debt investors.

Entrepreneurs realize the value created by PFAN and many of the companies maintain long-term relationships with their PFAN advisors. PFAN works towards enhancing local ecosystems for climate action funding. PFAN advisors are locally based and can provide value to project developers and in many instances their value goes beyond assisting in funding and they provide market-based insights, stronger connections within the ecosystem, helping with subsequent rounds of funding, introduction to other entrepreneurs in similar businesses across geographies.

PFAN's network includes two categories of partners that help to leverage and expand the impact of the expert network. These categories are: 'Network Partners', who help PFAN reach out to project developers and tap into existing networks for project origination; and 'Investment Partners', who rely on PFAN to support identification of project investment opportunities that meet their investment criteria.

PFAN receives its funding from donor agencies, and funding for PFAN in the initial decade came largely from USAID and METI of Japan. Since 2016, PFAN has been hosted by UNIDO and the Renewable Energy and Energy Efficiency Partnership (REEEP), with funding coming from the Governments of Australia, Austria, Japan, Norway, Sweden and the United States as well as from the Kigali Cooling Programme.

UNIDO operates a multi-donor trust fund, and REEEP executes the implementation, which includes coaching and advisory services, investment facilitation, events, and a limited amount of grant funding. PFAN uses a proven low-overhead business model, and for every $1 of donor support provided PFAN typically helps raise in the range of $60-80 of climate and clean energy investment.

Since its inception, PFAN has provided advisory services to over 700 projects and a total of 173 of these have succeeded in raising a cumulative total of more than 2 billion of financing for their climate and clean energy initiatives (for more information, see www.pfan.net).

Other Project Preparation Programs
PFAN is somewhat unique in the longevity and focus of its activities, in that it targets transaction advisory exclusively, and does not provide broader donor-support such as technical assistance or issues related to policy and regulatory support for climate and clean energy. There are some other programs with a similar focus on delivering transaction advisory services. Among these programs is GET Invest, which is funded by the European Union (EU).

GET.invest aims at mobilizing the private sector by building a pipeline of viable investment projects, with a focus on decentralized renewable energy. It supports private sector business and project developers, financiers and regulators in building sustainable energy markets. In doing so, it contributes directly to the interlinked sustainable development goals (SDGs) and the Paris Climate Targets. Launched in early 2019, Get.invest built on the activities of its predecessor program, the Africa-EU Renewable Energy Cooperation Programme (RECP), but with an extended geographical focus beyond the African continent.

The programme works closely with a broad range of partners, in particular industry associations, and cooperates with numerous related initiatives in the space of international cooperation on decentralised renewable energy.

GET.invest and PFAN cooperate in selected markets, including the Caribbean and coordinate activities closely in Sub-Saharan Africa and the Pacific.

than five-fold.[11] While such exits are rare, this example demonstrates that they are possible.

Exit through refinancing. One approach to exits is to bundle and refinance projects. In January 2018, Sindicatum Renewable Energy Co Pte Ltd, a manager of renewable energy assets, completed a green bond issuance of USD 39.4m (INR 2.5 billion) to refinance debt and fund projects in India. The bonds were guaranteed by UK development finance company GuarantCo, and received an A1 rating by Moody's and a AA-rating by Fitch.[12]

Later in 2018, GuarantCo signed a deal with Sindicatum for USD 60 million of green bonds covering tranches in India and the Philippines. The green bonds are synthetic local currency issuances in INR and PhP, but issued and settled in USD. GuarantCo's guarantees will be denominated in INR and PhP making it a local currency transaction, as are the majority of all GuarantCo's transactions.[13] For this issuance, the India tranche was rated A1 by Moody's, and the Philippines tranche was rated AA- by Fitch.

India M&A Deals. Another example of recent exits can be seen in the historic rise in renewable energy merger and acquisition (M&A) deals this year in India, despite the coronavirus pandemic that has taken a toll on economic activity. For example, there has been a significant rise in M&A transactions in India over the past several years. According to PwC, the disclosed value of M&A deals in India was about USD 2.7 billion in 2019 and USD 4 billion in 2020. Firm estimates are difficult to make, given that not all transactions are publicly reported. And in just the first quarter of 2021, India added just over 2 gigawatts (GW) of grid-connected solar power generation capacity.[14]

Financing Strategies

A major area where SME project developers need assistance is in developing a capital structure for their projects and businesses and a strategy for approaching investors. Many project developers have backgrounds in technology, or are entrepreneurs without financial experience or training. As a result, they do not have an understanding of issues such as (a) how to assess their working capital and determine the optimum funding path for their project; (b) whether they need equity or debt, or a combination thereof; (c) how to time their capital raise; (d) the basics and importance of proper equity valuation; and (e) how to manage dilution when new investors come into the picture.

Distributed energy service companies (DESCOs) in particular struggle in the early growth and market creation phases. They do not have sufficient cash flow or collateral to be able to raise significant debt; the company valuation is unlikely to be high enough to raise sufficient equity amounts without unacceptably high levels of dilution and negating developer value. From an investor's point of view there is not enough good quality data to facilitate and underpin quality investment decisions. The company requires increased runway to be able to gather and prove data and make it to a later financial close. This is where the development of innovative financing instruments comes in.

Below we share our experience of useful financing instruments and strategies we have recently been successfully deploying with SME project developers which we have been supporting as well as some new ideas and approaches we have been working on to address these challenges. These products are attractive because they address many of the challenges of these SME companies and projects noted above and are gradually enabling us to also increase access of SME's to a larger pool of financing in the wholesale capital markets.

Mezzanine Finance

For early-stage SME companies and projects, mezzanine finance is a flexible tool that helps bridge the missing middle gap and sits, as its name suggests, somewhere between equity and debt. It is unsecured (ie does not require collateral) and as such is considered to be "high risk"; as a result investors generally charge a higher interest rate than the rate on senior debt, which is debt that a company must repay first if it goes out of business. Mezzanine finance also generally has shorter tenors than other debt in a project. Mezzanine finance is usually highly structured and takes many forms including: convertible notes, subordinated debt, guaranteed preference shares, warrants etc. Traditionally mezzanine finance has not been available to SMEs in developing / emerging economies because of the higher risks in such markets.

11 https://acumen.org/blog/acumen-exits-orb-energy/
12 See https://renewablesnow.com/news/sindicatum-renewable-issues-inr-25bn-green-bond-599570
13 GuarantCo, a Private Infrastructure Development Group (PIDG) company, provided the guarantee in support of a USD 15 million 5-year INR tranche, a USD 25 million 7-year INR tranche and a USD 20 million 10-year PhP tranche, totalling USD 60 million senior local currency Green Bonds with investors benefiting from a 100% guarantee.
14 See https://energy.economictimes.indiatimes.com/news/renewable/india-added-2105-mw-grid-connected-solar-capacity-in-q1-2021-bridge-to-india/83030693

An interesting recent example of mezzanine financing for a project that we supported was **Fourth Partner** Energy. Fourth Partner Energy is a developer of solar rooftop PV for commercial and industrial facilities. The company has had several rounds of funding to expand its solar rooftop assets, but faced challenges during the pandemic in 2020. However, based on their strong business fundamentals, they were able to raise USD 16 million in mezzanine funding from a consortium of European impact investment funds, led by Symbiotics. **Fourth Partner** will utilize these funds to expand its business through construction of 150 MW worth of new solar assets.[15]

One of the key features and benefits of mezzanine finance is the ability to defer risk pricing and valuation decisions while ensuring a baseline / minimum return for an investor and allowing participation in any upside. This is the thinking behind convertible notes for instance, where a certain amount of debt converts into equity at a later stage at an agreed valuation; in the meantime, the investor's minimum return is protected through the agreed interest rate. This helps extend the project runway, allowing for development of the commercial aspects of the business model, while allowing for the gathering and analysis of more data thereby providing greater clarity on company valuation when the conversion happens. The case study on **Okra Solar** in text box 2 provides a further example of the deployment of convertible notes. To this end we are now also experimenting with convertible notes which convert to debt or equity and / or grant depending on the company performance and looking to set up micro-mezzanine funds deploying this early-stage innovative instrument in Sub-Saharan Africa. In our experience it is critical that this sort of financing is structured as commercially as possible. While grant financing has an undoubted role to play, particularly if structured as a results-based financing mechanism (RBF), there is always a risk that "free money" corrupts the business model or distorts the market in a way that is hard to understand, thereby further complicating the investment analysis and clouding the valuation.

Revenue Based Debt

Revenue based debt is another form of mezzanine finance which we are also seeing increasingly deployed, particularly where SMEs don't yet exhibit a pathway to investment scale or offer a clear exit opportunity for investors, but which are growing revenue quickly from a low base. The main benefit of a revenue-based financing vehicle is that it can provide a risk / return profile that is in between traditional debt and equity. Revenue-based financing typically involves repayment through agreed percentage shares in the revenue of a growing business. This locks in a return for the investor and allows participation in the commercial upside, which however cannot be calculated with certainty at the time of the transaction. The company owners avoid premature dilution and can expect a higher valuation for a larger company with a later equity raise at completion. This approach has been gaining favor in recent years in the venture capital industry for investments into growth-stage companies.

Micro Venture Capital

Micro Venture Capital (Micro VC) fills an early-stage funding gap between early-stage angel investors and later-stage institutional investors. Micro-VCs have emerged as promising players in the early-stage funding space to support projects with much-needed risk capital as well as hands-on mentorship. They focus primarily on extending support beyond capital to offer network access, expert guidance, help with future fundraising, and guiding project developers through their growth phase.

Micro VC is a new form of finance for early-stage projects in a market segment – often called the "Valley of Death – where developers have limited financing options, due to the higher project risks and difficulties in gathering the information needed to properly assess project risks and opportunities. This early-stage phase is particularly treacherous for clean technology development companies, which often face much longer journeys to market.

Micro VCs are usually established as funds of less than USD 30 million, and typically provide initial seed capital, which is raised in the formation of a start-up company and for initial activities such as acquisition of technology, market assessments, technical feasibility studies, and development of a business plan.

Bundling Investment Approaches

Bundling or aggregation refers to the process of combining project and / or company financing assets (as wholes or parts) into a portfolio to create efficiencies and economies of scale. The benefits include reduced costs, mitigation of risks, and reaching an investment "ticket size" that is more attrac-

[15] https://www.thehindubusinessline.com/companies/fourth-partner-energy-raises-16-mn-from-european-consortium-of-lenders-to-expand-project-portfolio/article32627797.ece

tive to investors. Bundling requires aggregation of assets into a portfolio to attract more private investors through the increased size and portfolio de-risking. The bundles or portfolios need to consist of similar types of assets (eg solar home systems), underpinned by similar contractual modalities and risk profiles. The pay as you go (PAYG) approach to financing the distribution of solar home systems and cook stoves to off-grid rural households is in essence a bundling strategy, whereby small individual loans (eg USD 70 – 500 per unit) to individuals and households are refinanced and managed at a portfolio level by the distributor, which uses its own balance sheet and third-party financing to act as a financial intermediary. The case studies of **Atec** & **Vitalite** (see below) exemplify this strategy. In theory, it is then possible to further aggregate and refinance these portfolios freeing up the balance sheets of the DESCO distributors to write more new business and scale more aggressively than otherwise.

Taking this idea further, PFAN has been looking for some time at financial aggregation of portfolios of projects and companies sharing similar business models, risk profiles and geographies (eg solar rooftop, small hydro IPPs). While the approach in theory appears quite feasible, in practice it is proving challenging to execute, mainly due to high transaction costs associated with the aggregation process: each asset / business / project still needs to be individually verified as conforming to the targeted aggregation criteria for due diligence and risk and return assessments and the aggregation can be perceived as a conglomeration (increase) of risk rather than the hoped-for diversification. This approach does however seem to hold some promise as a refinancing strategy for already commissioned / operating projects and businesses, thereby also offering another potential exit route and helping to develop much needed liquidity in the secondary market.

Funds are in essence bundling / aggregation instruments and they have been proven to work. For this reason, we are pursuing the micro-mezzanine fund approach mentioned above as a first step. But we are also looking at how we aggregate SME company and project assets to access wholesale capital markets through securitisation and bond instruments.

Green Bonds and Climate Themed Bonds

We have seen green, climate themed and so called ESG-bonds (Environment-Sustainability-Governance) start to gain traction among issuers of large corporate and public / sovereign bonds. Some financial institutions and intermediaries are now also structuring these green and climate bonds to aggregate assets of smaller SME companies and issues, using them principally as a route for refinancing companies and projects that are already in operation at some scale. We are working with a number of these issuers, particularly in Asia, to understand how we can use green and climate bond instruments to fund companies and projects within our portfolio, thus opening up wholesale capital markets to SME access. The case study on **LankaBangla Finance Ltd** in text box 2 illustrates this approach. Other opportunities for deployment of this sort of approach are in the re-financing of repowering (upgrading) of existing solar farms and wind farms, capitalizing on efficiency gains of updated and improved technologies by the exchange of new equipment for old. PFAN is seeing a number of these sort of deals, especially in Asia, seeking to increase the energy and financial yield on existing transactions

One of the challenges that PFAN is facing revolves around certification and verification of these bonds – especially related to clarifying the "use of proceeds". What exactly comprises a "green" or a "climate" asset? How is ESG defined, and who verifies whether the assets meet the criteria? How do we avoid the accusation of green washing? There are many conversations around these issues and as yet no real consensus, although the new EU Taxonomy looks to provide a de facto set of criteria for the industry. Against this background PFAN sees its role as preparing and vetting assets for inclusion in these sort of financing packages by providing the up-front expertise that SMEs need to go through compliance and verification and by de-risking the company and projects assets as much as possible so that they can be included in the first place.

In the medium term, we see green or climate-themed bonds as becoming an important tool in the toolbox to be able to tap into larger pools of capital for financing SME company and project developers of climate and clean energy projects.

Gender Lens Investment

Bringing a gender lens to climate projects, and a climate-lens to gender projects may unlock new investment opportunities in public and private markets. Gender lens investing is a rapidly growing movement and a growing body of research clearly links gender diversity in leadership and the workforce to financial returns, lower risk, and sustainable growth. Women are innovators and entrepreneurs creating disruptive solutions to the climate crisis and addressing gender in product or service design may unlock products and services that are more responsive to market needs. Women in distribution channels, marketing, or sales may be the key to a competitive edge for a company. And as consumers, women make 80% of household buying decisions worldwide, and often constitute key market segments that deliver green growth and impact.

Tapping into this movement, PFAN is applying a gender lens investment approach across its whole activity from project origination through the project development and preparation process and into investment facilitation. This involves proactive capacity building and awareness raising at all levels of the operation to address and remove ingrained bias as well as to focus in on, emphasise and exploit the opportunities for improved investment returns. This approach increasingly resonates with our investment partners as well as our project developers and entrepreneurs and is already being seen to produce enhanced deal flow.

Reflections and the Way Forward

As pressure builds on the global community to step up to the climate challenge, there remains a need to ensure greater financial flows over and above public finance to meet technology transfer needs, especially in lower- and middle-income countries. Ensuring these financial flows can support both climate action in mitigation and adaptation as well as supporting the attainment of the Sustainable Development Goals is key.

Because of the need to scale financing, investment for many projects may only be available from traditional channels of finance, who are primarily interested in larger investment levels for their projects, to reduce risk and transaction cost. Meanwhile SMEs, which have tremendous potential for climate action and impact, continue to struggle to access financing for their projects and businesses, despite the large flows of capital which are now available. As we have seen they face particular challenges with:

- low execution capacity
- limited access to resources to carry out all of the project development activities
- difficult access to startup and growth capital
- missing hard data and confidence on projections and financials
- lack of track records

The development process is laborious and long with many stops and starts, making it difficult and costly for SME project developers and entrepreneurs to move to investment scale. With the global imperative of managing climate change to within manageable thresholds, blended finance combining varying levels of risk-return investors, combined with grant funding and technical assistance support remains key to unlocking investment in these frontier markets for small and medium projects. The capacity of climate initiatives to gather and collate appropriate development metrics opens further investment potential from the impact investment sector.

Looking forward, the importance of data generation, collection and interpretation will increase and help define open and grow new markets in the way that we are currently seeing energy access markets at the bottom of the pyramid now be accessed. This data and the ability to manipulate it will likely facilitate the commoditization of hitherto high-cost products and services to larger and better targeted (and understood) groups of customers, thereby accelerating the continuing trends to bundling of assets and lowering financial scale thresholds. The value of the last mile access market will likely increase dramatically in the next 10 years or so.

The financial sector is looking keenly at the bankability of these propositions and creating new financing instruments and asset classes to help price the risk of these frontier markets and new business models. The emergence and expansion of mobile communications and information platforms enhances the viability of many projects and companies, especially the growth of mobile money and the spread of the IOT. The need for relevant data for investment decision-making remains high and these technologies play an increasing role in quantifying, managing and pricing risk and facilitating fairer valuations and better investment decisions.

However, early-stage finance for SMEs is likely to remain a significant challenge for the foreseeable future, especially as government and donor budgets tighten in the wake of pandemic induced stimulus packages and notwithstanding the emphasis on green recovery. More coordinated and better focused project development and preparation support across the development value chain from initiatives like PFAN will accordingly continue to be critical in closing the gap in the missing middle and ensuring that capital flows more efficiently to small and medium innovative business models, which address untapped markets with new products and service offerings, delivered and enabled through a nexus of energy, climate, financial, information and communications technologies, thereby underpinning the energy transition.

Case Studies

Below we describe a range of case studies of PFAN projects in two of PFAN's historical markets – Asia and Africa. The case studies illustrate PFAN's support in financing and assisting in transfer of technology to Least Developed Countries. PFAN's support to these projects is aimed at meeting the needs of the project developer by providing assistance in business and financial planning for the project in order to mobilize capital for climate action projects in developing countries that will contribute to efforts to mitigate emissions of greenhouse gases, while increasing climate resilience.

Okra Solar (Cambodia)

Okra designs and sells proprietary IoT hardware along with software as a service technology to mini-grid developers and installers of solar home systems. Okra's core initial insight was the value of being able to connect homes with individual solar panels and turn the village into a "mesh grid" The hardware and software enables clusters of solar home systems and or mini-grids to be connected without the use of inverters and their power generation and consumption optimized accordingly, significantly reducing the investment costs. With PFAN support, Okra has raised a total of $1.3m million through a series of pre-seed and convertible note rounds of investment from reputed private equity funds. PFAN advised on suitable instruments, valuation and the impact on the developer's shareholding. Initially they started operations in South East Asia and currently actively working with mini-grid developers in Nigeria. PFAN as global network helps linkages across geographies where there are similar market conditions, enabling projects to expand and de-risk from geographical concentration. The company is continuing to scale its operations entering new markets in Africa and Asia.
Web: www.okrasolar.com

ME SOLshare Ltd (Bangladesh)

SOLshare has created a revolutionary new approach to bring affordable solar electricity to everyone in Bangladesh through its peer-to-peer solar energy trading platforms based on distributed ledger technology. In this model, houses with PV solar home systems can sell their excess solar electricity to others in their community. The technology also enables homeowners to top up their power remotely, and they can invest in more power generation and trade it off for a return with minimal risk. The company offers various products and services for solar off grid customers that enhance energy access.

PFAN helped SOLShare raise its first round of funding in 2018. This round of funding helped them to launch new products and expand the customer base. Since then, the company has raised 2 more rounds of funding. The SOLBox, a product from Bangladesh's SOLshare, won the first prize in the Empowering People Award 2019 competition organized by Siemens to support entrepreneurs around the world. They also won the Green Oscars -Ashden award in 2020 under Financial Innovation for Energy Access category
Web: www.me-solshare.com

ATEC Bio digesters (Cambodia)

ATEC is a social enterprise established in 2016 that provides the first plug-and-play household level bio digester, which can be installed in high-groundwater, earthquake and flooded areas –conditions that affect an estimated 89% of the target market in Cambodia as well as many other developing countries like Bangladesh, Myanmar or Indonesia. ATEC combines the biodigester with a wholesale and direct distribution model that effectively delivers the product to market in a scalable, sustainable manner. The biodigester systems help farmers to generate biogas as well fertilizer. PFAN helped ATEC to raise its first round of funding of $ 1 million in 2017. ATEC has since sold over 1800 biogas digestors, producing over 689 million liters of biogas and producing over 35 thousand tons of fertilizer.
Web: www.atecbio.com

Vitalite (Zambia)

VITALITE provides low-income households with high-quality distributed energy services. They sell Solar Home Systems (SHS) and appliances made by Fosera, a leading German manufacturer of high-quality Pico-Solar-Home-Systems designed for rural electrification. They provide consumer finance, using PAYGO technology, which ties energy service delivery to time-based payments. After the customer has paid off the full value of the system, they own it outright. Energy services offered by VITALITE (e.g., lighting, phone charging, mini sound systems, TVs, etc.) represent an improvement for off-grid households that have limited or no access to modern energy services.

PFAN began coaching this project in 2018, and provided grant assistance through its Tipping Point Technical Assistance (TPTA) mechanism, which was used to “unstick” a negotiation and cover some of the legal costs for the debenture, and this enabled closure on the $500,000 debenture agreement to fund inventory and help with the company’s expansion.
Web: www.vitalitegroup.com

Inspira Farms (Rwanda)
InspiraFarms address food losses in the first mile of fresh produce distribution by supplying modular and energy-efficient on-farm and close-to-farm cold rooms and packhouses for the horticultural sector in emerging markets, with a focus on African countries. PFAN supported this project in 2016 and following this they went on to raise debt and recently closed a series B fundraise.
Web: www.inspirafarms.com/

SokoFresh (Kenya)
SokoFresh offers affordable cold storage services to Kenyan farmers and agribusinesses, integrating this with market linkage services. SokoFresh targets the huge potential for cold storage for Kenyan smallholder farmers. The market may include as many as 5 million individuals and entrepreneurs, who are responsible for 90% of the country’s food production. The company was founded in 2018 by impact incubator and investor Enviu, as a result of discussions initiated as part of Enviu’s East African, Food to Market Programme. PFAN has supported the company develop their current finance raise of $5.5 million and supported their pitch on international platforms.
Web: www.sokofresh.co

Koolboks (Nigeria)
Koolboks is offering solar-powered freezers, equipped with Pay-As-You-Go technology and offered through an innovative cooling-as-a-service (CaaS) model, which enables eco-friendly and accessible refrigeration.The company sells its products through a network of distributors in 9 countries in Africa, and they facilitate asset financing and CaaS agreements for their end-customers. In 2020, Koolboks forecast revenue of $5.3M for 2022. PFAN has been assisting Koolbox in preparing their financial projections and devising and implementing an investment strategy.
Web: www.koolboks.org

Thule Khola Hydropower Project (Nepal)
Thulo Khola is a grid connected run of the river hydropower project with installed capacity of 21.30 MW. The project has power purchase agreement with Nepal Electricity Authority (Government of Nepal’s Organization for Electricity Production and Distribution). PFAN supported this project in identifying international equity investors, deal facilitation and due diligence processes. Investors required local currency hedging and also political risks cover in Nepal. PFAN assisted this through its network partners, structuring a customized solution tailored to investor needs.

Ather Energy (India)
Ather Energy was an e-mobility start-up, manufacturing and selling electric scooters to the Indian market which was shortlisted by PFAN at the prototype testing stage. PFAN supported the project in preparing their business plan, financial projections and investor presentation for its initial funding round. In the meantime, Ather has raised around US $158 million in 4 different rounds of equity funding. The company has sold more than 15.000 electric scooters in India in the last 3 years and has established and operates its own charging networks in Bangalore and Chennai. Ather’s factory now has an annual capacity of 110,000 scooters and 120,000 battery packs and the company has a presence in 27 cities across 15 states, making it a good example of a project which has managed to reach commercial and investment scale from scratch.
Web: www.atherenergy.com/

LankaBangla Finance Ltd (Bangladesh)
This Bangladeshi financial intermediary proposes to issue US$ 20 Mn Green Bonds in various formats such as Senior Unsecured Debt, Non-Preferred Senior Debt, Subordinated Debt and Covered Bonds. The proceeds will be used to refinance a portfolio of existing green investments, including industrial and commercial energy efficiency projects, clean energy projects, recycling, waste to energy and resource, pollution control or similar type of technology. PFAN is helping the issuer select and vet the assets and structure the portfolio. The transaction will be a first for Bangladesh and PFAN and, if successful, could help inform the design and development of copy-cat instruments in the future.
https://www.lankabangla.com/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"Hlanyela Sihlahla, Wonge Imvelo": Plant a Tree and Save the Environment in Eswatini

Abstract

The Kingdom of Eswatini embarked on an ambitious plan to plant 10 million trees within 5 years in September 2020, launched by the Prime Minister. Tree planting was prioritised under Eswatini's Technology Needs Assessment (TNA) in 2016 and has been part of national projects over the years, though in 2020 it was prioritised as an initiative under COVID-19 recovery and resilience building for climate change. In this article we describe how a simple, low-tech and inexpensive adaptation technology of tree planting was prioritised through a mix of top-down political will, volunteerism and bottom-up community action. Within a short period, a large number of indigenous, fruit and selected non-invasive trees were planted in the country, in accordance with the Department of Forestry's tree planting manual. The initiative saw the mushrooming of "mini forests" in urban areas for the first time in Eswatini, driven by the voluntary efforts of diverse stakeholders. We focus on the "orgware" part of tree planting as a climate change technology, highlighting the importance of strong political will combined with collective action, without any major external funding. We tell the story of how the campaign was initiated, how it was implemented and the driving forces and factors (both bottom-up and top-down) that helped the campaign gain momentum. Finally, we reflect on this experience to understand how such initiatives can be expanded and/or replicated elsewhere.

Introduction

Trees and forests are some of the most valuable resources we have and provide a number of ecosystem services. These include:

- absorbing carbon dioxide and releasing oxygen[i];
- reducing air pollution (by absorbing gases through leaf stoma) from ozone, carbon monoxide, sulphur dioxide and nitrogen dioxide[ii, iii]
- trapping particulate matter in leaves thereby cleaning the air[iv]
- carbon sequestration[v];
- biomass production, providing habitats for birds, insects and animals, pollination, seed dispersal, resistance to wind storms and cultural ecosystem services[vi].

In addition to these ecosystem services, trees and forests are the most important line of defence against climate change[vii]. Yet, deforestation is occurring worldwide at alarming rates, due to land use change, increasing demand for forest resources and expansion of agricultural land[viii]. Deforestation is a major driver of climate change as much of the carbon that is stored by trees is released, when trees are cut down or forests are burned. Unrestrained deforestation, coupled with hazards such as wild fires contribute to land degradation, leading to collapse of ecosystems, threatening human well-being[ix].

The African continent has lost 21.7% of its forests since 1900[x]. This has led to losses in soil organic carbon stocks and soil fertility[xi]. In the landlocked Kingdom of Eswatini, forests are under threat from land use change, cutting down of trees for use (for firewood and construction) by the local population, and the expansion of agricultural land and wildfires[xii]. According to Eswatini's Land Degradation Neutrality Report of 2018, 465,290ha or 27% of the country's land is degraded[xiii]. Climate change will exacerbate the risks to forests as projections show that Eswatini will continue to get warmer and rainfall will continue to be uncertain and difficult to predict, thereby affecting tree growth[xiv].

There are many benefits to preserving trees and developing tree cover. Studies have proven that there is a strong forest-rainfall connection, and the climatological effects of deforestation include reduced rainfall[xv]. Furthermore, trees and forests can conserve soil surface against erosion through the binding of their dense root system, thereby contributing mitigating land degradation. Tree planting is therefore a key means to address the land degradation issue and contribute towards reducing the negative impacts of climate change.

Given the above challenges, risks and context for Eswatini, the timing was right for a national tree planting initiative. This was launched during the COVID-19 recovery period in Sept 2020, by the Prime Minister of Eswatini. The campaign was called "*Hlanyela Sihlahla, Wonge Imvelo*" which means "Plant a Tree and Save the Environment". The aim of the campaign is to reduce land degradation through planting of indigenous, fruit and selected non-invasive tree species as a way of reducing pressure and dependence on forests for fuelwood and fruits, while creating income for communities and local schools. The ambition of the country is to plant 10 million trees in a period of 5 years.

The technology of Tree Planting

We characterise tree planting as a climate change "technology", incorporating elements of hardware, software and orgware as defined by the analytical framework used in the "Technology Needs Assessments" or TNAs[xvi]. The 'hardware' dimension is the tangible aspects, such as equipment and products, in this case, the tree seedlings themselves; the 'software' dimension is the knowledge associated with the production and use of the hardware (the tree planting manual); and the 'orgware' dimension is the institutional and policy framework, involved in the adoption and diffusion process of the technology. In fact, tree planting was included in the larger list of technologies under the adaptation component of Eswatini's TNA, which was conducted between 2016-2018. In this article we unpack each of these technology dimensions in the context of the tree planting campaign.

Hardware: the tree seedlings

The hardware dimension of this technology is the actual tree seedlings used for afforestation and reforestation. These are produced in the Department of Forestry's tree nurseries and other private nurseries, as well as nurseries set up by environmental projects across the country at community level. There are six (6) government nurseries managed by the department of forestry and nine (9) private nurseries from which planted seedlings were sourced. The hardware intensity was low as tree seedlings could also be produced at community level.

Software: Tree Planting Manual

The software dimension refers to the tree planting manual produced by Department of Forestry in collaboration with Strengthening National Protected Areas (SNPAS) project and Participatory Ecological Land Use Management (PELUM) in early 2020. A total of one hundred (100) hard copies of the manual were produced and shared with the stakeholders and also electronically with members of the public. The manual contains information on 38 indigenous species suitable for different ecological zones in the country. It provides technical information on situation analysis, site preparation, species selection and guidance on professional tree planting as well as information on caring for the trees after planting[xvii] (SNPAS, 2020). This manual was used during establishment of mini forests and for planting trees around the country as part of the campaign.

Orgware: the Institutional and Policy framework

The Department of Forestry spearheads tree planting activities in the country and is situated within the Ministry of Tourism and Environmental affairs, providing institutional support for these activities. The Kingdom of Eswatini is party to several international conventions aimed at increasing tree canopy cover for positive environmental benefits. These include the UN Convention on Biological diversity, UN Convention to Combat Desertification and the UN Framework Convention on Climate Change to mention a few[xviii]. The planting of trees in the Kingdom of Eswatini is strongly supported by the National Forest Policy of 2002 and the Flora Protection Act No.5 of 2001 which prohibits the cutting and sale of indigenous flora hence promoting sustainable management, utilization and conservation of forest resources. The National Biodiversity Strategy and Action Plan also commits the country to afforestation efforts to halt species and habitat loss[xix].

Thus, tree planting as a technology had all the hardware, software and orgware dimensions in place for its implementation and adoption. Next, we look at the driving forces and the chronological sequences of events leading to the campaign.

Driving forces for tree planting campaign

The idea of the tree planting campaign was initiated by the "Tourism and Economic Recovery Task Team for Unlocking Climate Finance", which was set up in May 2020 by the Hon. Minister of Tourism and Environmental Affairs as a response towards COVID-19 recovery. This committee was tasked to come up with proposals to both address climate change and revive the economy. The TNA adaptation report was a point of reference for the committee during the proposal development process as it included climate change adaptation and mitigation technologies prioritised in the country (including tree planting as a technology). In addition, most members of the committee have strong environmental awareness and understood the benefits of tree cover as a climate response but also as an opportunity to generate short term jobs for economic recovery. The COVID-19 pandemic response in Eswatini included guidance that mass gatherings could only happen in open spaces and tree planting was an activity that ticked most of the boxes and appealed to the majority of the members. The committee was inspired by media reports from Ethiopia and Pakistan of their mass tree planting initiatives and hence there was an element of South-South "technology transfer" that informed the tree planting programme in Eswatini. Additionally, the committee put forth the idea of establishing "mini forests" in urban areas. This was inspired by the work of Japanese botanist Akira Miyawaki, who encouraged planting saplings close together, using native varieties adapted to local conditions to recreate layers of a natural forest[xx].

The tree planting proposal was jointly developed with the Department of Forestry (within the Ministry of Tourism and Environmental Affairs (MTEA)) and after the initial concept was ready, the Department brought together relevant stakeholders including municipalities to take the work forward after the official launch of the campaign by the Prime Minister. There was strong interest from local institutions and as a result the tree planting campaign took off without formal external funding, successfully planting 112,436 trees from its launch in September 2020 until July 4, 2021, including the establishment of mini forests for the first time in the country.

Tree planting activity can be safely done during COVID-19 as the activity is outdoors and there is scope for safe distancing. When executed with formal funding, it can create temporary jobs that do not require too much training and can provide income particularly for those who lost their livelihoods due to the pandemic. The launch of the tree planting campaign included a symbolic tree planting exercise (in Sept 2020) at the Matsapha landfill rehabilitation site, where 200 trees were planted by various dignitaries present at the occasion.

The municipalities then produced maps of open green spaces where mini forests could be established. The first mini forest was set up by the Indian High Commission in collaboration with the Mbabane City Council and the Mayor in October 2020, to coincide with Mahatma Gandhi's 150th birthday, with a symbolic planting of 150 trees. The Coronation Park, an open green space in Mbabane City was the location of the establishment of the first mini forest with the inaugural tree planted by the Minister of MTEA. The Indian High Commissioner gave an inspiring message at the event, "Maintenance of cleanliness and development of a green environment were corner stones of Mahatma Gandhi's way of life which he propagated during his two decade long stay in South Africa as well as during the freedom struggle period in India. His motto of 'be the change you want to see' has inspired hundreds of thousands of people all over the world", she said. The Minister of MTEA encouraged residents of Mbabane to plant more trees and combat climate change.

Following this, another mini forest was established at Selection Park in Mbabane in collaboration with Eswatini Women Parliamentarians and the Indian High Commissioner on the 26th October 2020 where 25 indigenous trees were planted. So far, in total, five mini forests have been established with two in Mbabane, one in Matsapha landfill site, one in Ezulwini and one in Manzini. These were supported by sponsors including the United Nations Development Programme (UNDP), Matsapha Town Board, Manzini Municipality, Ezulwini Municipality, Mbabane Municipality and the Indian High Commission. The private sector supported tree planting in schools and charitable missions including support for fencing off areas to protect the trees in mini forest sites.

Community groups, private sector, schools, prisons and other stakeholders joined the campaign and the country saw the mushrooming of mini forests in three cities. Thus, the tree planting campaign in Eswatini was a mix of top-down and bottom-up approaches. The committee and the Department of Forestry were able to mobilise both high-level political action, and grassroot level voluntary action, despite lack of external funding the campaign was successful and continues forward with growing support.

The political will is strong and clearly demonstrated by the Prime Minister's words, "The ambition is to plant 10 million trees within 5 years with indigenous and high value species for improved livelihoods, reduced land degradation, improved conservation of genetic materials, enhanced biodiversity, as well as to contribute towards COVID-19 recovery and resilience to climate change. This is in alignment with the country's National Climate Change Strategy and Action Plan, environmental goals and the ambitions of the Nationally Determined Contributions".

Progress of Tree Planting

Chart 1 shows the various partners who supported the campaign and number of trees planted since the launch.

The role of media

Another success factor for the tree planting campaign was the encouragement and visibility from the media. The media publicised tree planting and through that, stakeholders such as the United States (US) Embassy came forward and approached the Eswatini Environment Authority (EEA) to participate in the campaign. EEA then worked together with the Department of Forestry to identify a community care point for orphaned children to plant trees including fruit trees. The US Embassy sponsored planting of 250 trees including 30 fruit trees on 22 April 2021 at the children's care point. This brought the total number of tree planted since the campaign began in Sep 2020, to 110,820.

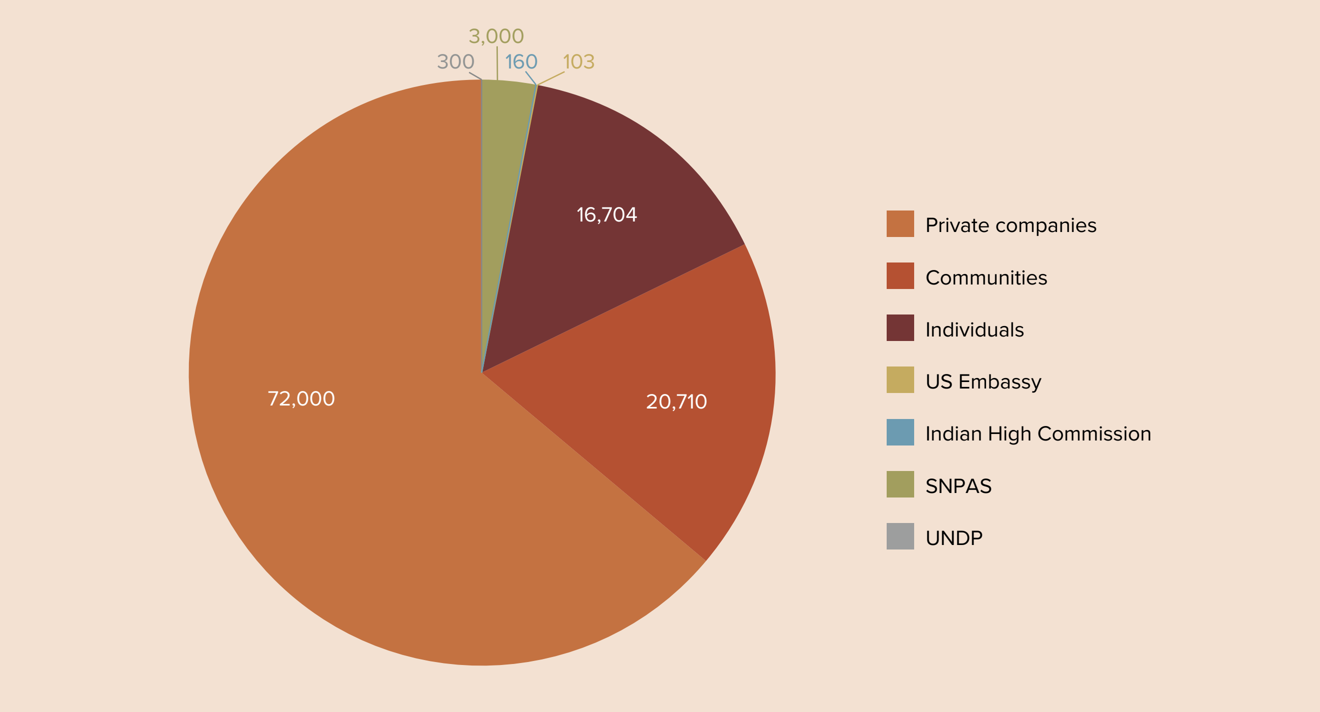
Conclusions and Recommendations

While Eswatini's carbon emissions are a tiny fraction of the global total[xxi] (MTEA, 2016), the country has been progressing with climate action, including developing a national climate change policy, strategy and action plan, implementing climate change adaptation and mitigation projects. Tree planting and the management of ecological infrastructure is included in Eswatini's first Nationally Determined Contribution (NDC) to the Paris Agreement. In this article we have shown that Eswatini has launched a project to rollout this priority climate change adaptation technology, through a carefully designed and executed campaign, aligned with the NDC and related development ambitions. The wide adoption of tree planting was possible due to all the hardware, software and orgware dimensions of technology being available.

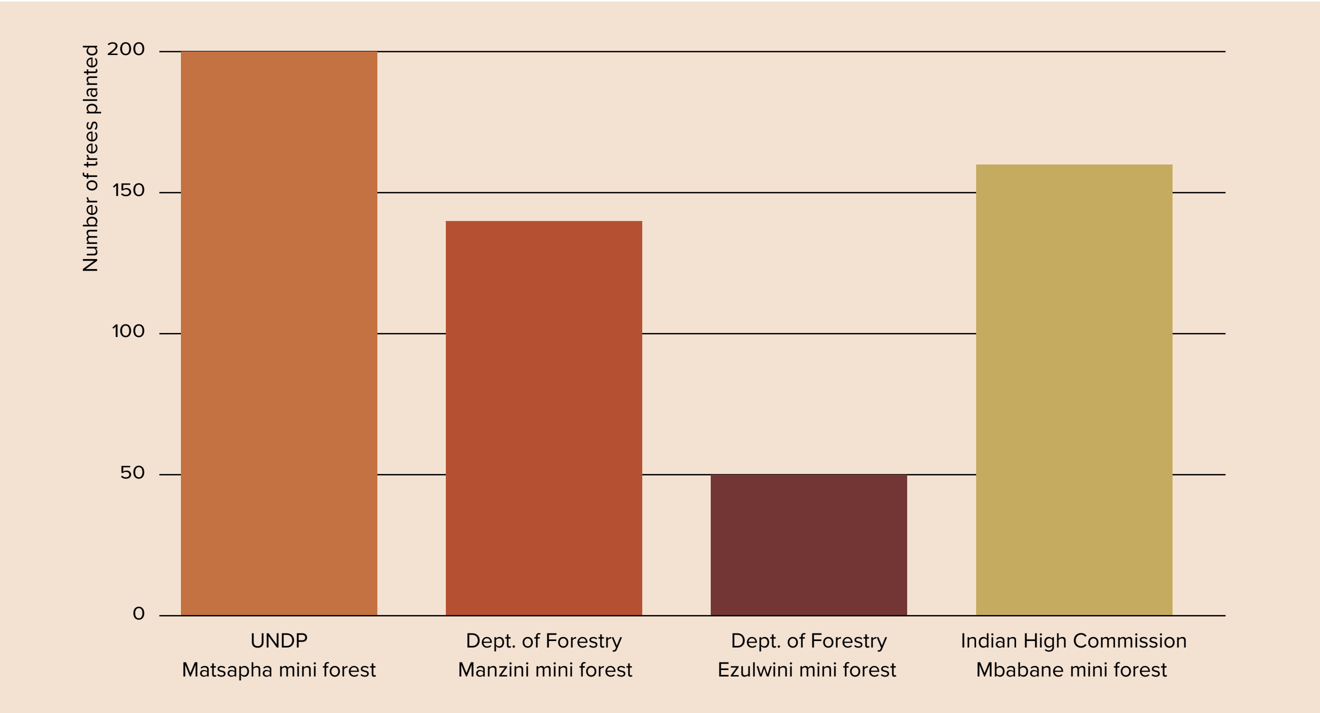
In order for the country to achieve the target of planting 10 million trees in five years, there is need for further support to scale up efforts. Some recommendations for this are provided below:

1. Provide support to the Dept. of Forestry to increase production capacity of nurseries and provide training for staff involved in tree production in the nurseries.

Chart 1: Partners supporting the Tree Planting Programme in Eswatini with numbers of trees planted



Graph 1: Sites with Mini forests, partners and number of indigenous trees planted per forest.



2. Translate the tree-planting manual to local language and expand the scope with addition of more indigenous tree species.
3. Mobilize more stakeholders for tree planting particularly the youth, such as school children, university students and other youth networks (such as the Eswatini Youth Biodiversity Network) to ensure sustainability for the future.
4. Promote tree planting activities through visibility in the media and through recognizing and appreciating those who plant trees voluntarily.
5. Develop proposals to raise funds for scaling up tree planting activities across the country.

In summary tree planting is a quick win for capturing carbon emissions, restoring degraded land, preserving habitats for biodiversity and for making urban areas more aesthetically pleasing. It has multiple benefits for the country and helps achieve the country's climate action aspirations as well as all the sustainable development goals. Eswatini should build on the momentum gained so far, especially the high level of community interest and involvement in tree planting, since the launch of the campaign. To plant 10 million trees within 5 years is an ambitious goal, but it is an achievable one and a wise investment for future generations to enjoy a green legacy.

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Scaling up investment in climate technologies in Uganda: road signs, roadblocks and expressways to implementation in support of the Paris Agreement

Abstract

In response to the Paris Agreement, Uganda developed and submitted a Nationally Determined Contribution (NDC), which prioritizes reducing the vulnerability of its population, environment and economy through implementation of adaptation actions. In this article, we leverage the results of the recently concluded climate Technology Needs Assessment (TNA) in Uganda and the available literature to identify some of the road signs for, and roadblocks to, scaling up climate technologies. We focus on the results of the multi-criteria analysis, which identified rooftop solar systems and rooftop water harvesting as the most optimal technology options in the energy and water sectors respectively. We use these two technologies as case studies and explore the barriers (roadblocks) that hinder their transfer and adoption as well as core elements of an enabling framework that can help overcome the barriers to investment in large-scale technology rollout.

Introduction

Climate technology development requires investment from both the public and private sector. In this regard, the public sector R&D that played an important catalytic role in developing some of the key technologies of the 20th century is also playing a role in the transition to low-carbon energy technologies. Climate change has already inspired the development of environmentally sound technologies, including those that are capable of reducing greenhouse gas emissions.

Explicit and strong government support in the form of tax incentives, R&D grants, favourable regulatory frameworks, and government expenditure policies are strong catalysts for the development of environmentally sound technologies[i] . These interventions are particularly imperative for developing countries where incentives for private sector investments in developing such technologies are limited.

Uganda's estimated carbon dioxide emissions are 1.39 tons per capita, far below the global average of approximately 7.99 tons. The country's emissions account for approximately 0.099% of the global total, thus contributing very little to the potentially catastrophic build-up of the anthropogenic greenhouse gases (GHG) in the atmosphere. Yet the country is among the most vulnerable to global warming and climate change impacts. Nonetheless, Uganda is fully committed to fulfilling her commitments under the respective article of the Convention on Climate Change; particularly the principle of "common but differentiated responsibilities and respective capacities"[ii].

In response to the Paris Agreement, Uganda developed and submitted am NDC that prioritizes reducing the vulnerability of its population, environment and economy through the implementation of adaptation actions. The country pursues strategies, plans and actions for low carbon development. The mitigation and adaptation intentions are based on the country's National Climate Change Policy (2015), which reflects Uganda Vision 2040[iii].

Nationally determined contributions, long-term low carbon development strategies, technology needs assessments (TNAs), national adaptation plans and technology road maps are some of the planning tools and processes that are key in facilitating the implementation of mitigation and adaptation actions that Uganda has identified.

The primary focus of Uganda's NDC is adaptation under which the country is focussing on reducing vulnerability and addressing adaptation in agriculture and livestock, forestry, infrastructure (with an emphasis on human settlements, social infrastructure and transport), water, energy, health and disaster risk management. Through sustainable land management and Climate Smart Agriculture (CSA), Uganda also plans to increase her resilience at the grassroots level. Under mitigation, the country continues to focus on energy supply, forestry and wetland sectors.

Climate technologies are technologies that can support the transition to low carbon societies and ensure climate resilience. They include hardware, the knowledge involved in producing and using them as well as the enabling frameworks and business models which facilitate their marketing. Technology transfer includes human capabilities and capacity to repair, maintain, adapt, localize and innovate the hardware and the "orgware" that is being transferred.[iv] Transfer, diffusion and uptake of climate technologies therefore refer to the processes and mechanisms that enable markets to function and users to adopt new technologies.

A number of factors and barriers affect the technology value chain and pose roadblocks to the transfer, diffusion, uptake and scaling up climate technology. Some of the success factors that could be considered as signs for successful diffusion of technologies include the availability of a skilled and competent workforce, supportive policy and institutional frameworks, accessible finance for end-users and businesses as well as business models that work. Some of these factors are discussed below:

Infrastructure

Uganda recently undertook a climate technology needs assessment under phase III of the project supported by the Global Environment Facility (GEF). During the project, which was implemented by the United Nations Environment Programme (UNEP) and the UNEP DTU Partnership (UDP) in collaboration with University of Cape Town, 12 technologies were prioritized in the agriculture, forestry, water and energy sectors. These technologies can be readily accessed through private sector providers and civil society organizations (CSOs) involved in development work and are not entirely new to Uganda. However, scaling them up requires specialized facilities or modification of existing facilities to cater for mass production and distribution in certain instances. This may further entail involvement of new actors (investors), and consequently, a need for licensing agreements and other modalities for technology transfer. A solid knowledge base of the value chains for these technologies is critical for sustaining the gains from deploying them to meet Uganda's adaptation and mitigation ambitions.

Institutional and policy framework

Overall, Uganda has policies which, to varying extents, support the implementation of climate ambitions through the deployment of environmentally sound technologies in the respective sectors. The priorities in the National Climate Change Policy have been integrated in the Second National Development Plans (NDP) 2020/21-2025/2026 (2015). In the long term, Uganda intends to follow a climate-resilient and low-carbon development path linked to green growth and broader sustainable development goals. What remains is for deliberate investment and implementation of targeted grass roots level programs and monitoring and evaluation of the impacts of these interventions, as well as the effectiveness of the policies. However, a critical analysis indicated some inconsistencies and contradictions among some of the policies, which make them counterproductive to efforts in other sectors. This can be addressed through sector-wide approaches in implementation programs, and involvement of all critical actors at the onset, across the technology value chain. Overall, there is need for improved policy frameworks including improved R&D, climate cooperation and strengthened technology networks between countries and among the various climate change actors.

Technology Transfer

Both public and the private sectors evidently play complementary roles in facilitating transfer of environmentally sound technologies. Technology transfer is driven by knowledge from both exogenous and endogenous sources. However, successful transfer of environmentally sound technologies to address the country's NDC ambitions is to a large extent dependent on information available to all actors in the value chain. For instance, researchers and technology developers require information about intellectual property rights and how to protect their products. Private sector service providers on the other hand will want to know how to apply for licenses or subsidies; what the markets are like and which technologies are in demand by the population among other things.

Financing

Financing is critical for supporting R&D as well as advancing technology transfer. Financial resources are critical for the provision of start-up capital, product development, intellectual property (IP) protection, commercialization, and scaling up of technologies. Financing could take the form of grants, loans or subsidies to support product development (research) and commercializing of the technologies in the case of private sector. They can also help the private sector develop prototypes and pilot them as a means to attract business partners, develop implementable business plans, and identify their niche in the market. On the demand side, grants, loans and subsidies can provide incentives for adoption of the identified technologies.

Human Capital Development

The nature of human capital among the technology service providers determines the quality and sophistication of technology options they focus on. However, the tendency for entrepreneurs in the developing world to cut costs by avoiding highly skilled human resources implies that countries like Uganda risk focusing on technologies that demand lower technical skills sets. This results in a gravitation towards products that are less technically demanding as opposed to those that require continuous innovation. A case in point is domestic rainwater harvesting (RWH) where the Ugandan government's 'self-supply' policy encourages households to access water through their own efforts[v] by making incremental improvements to their supply using local and easy-to-replicate solutions. This approach treats RWH as a process that simply captures increments of physical water to satisfy demand while not taking into account the need to understand the wider interactions that take place between people and water. Jepson et al.[vi] also suggest that household water security should be conceptualized as emerging from a 'hydro-social' process that requires innovative approaches.

Besides providing an enabling environment through appropriate policies and laws, government is also responsible for providing opportunities for specialized skilling and re-tooling of human resources that are responsive to the changing technology capacity needs of society, due to climate change. Government also has a role in setting standards for technology products and training programs for product developers and ensuring adherence to them.

Networks and partnerships

Networks and partnerships among government actors, policy makers, private sector and academia are critical for ensuring access to complementary knowledge, decision-makers/people of influence; and resources such as physical infrastructure, and other materials that could otherwise have been inaccessible if actors worked in isolation. The internet has played a significant role in providing access to information and positive change at country and global level.

Climate technologies in Uganda

In an effort to identify and prioritize climate change mitigation and adaptation technologies, the Government of Uganda undertook a Technology Needs Assessment (TNA) from 2018 – 2021. The assessment identified key priority sectors that are most vulnerable to climate change. Through the process, Uganda has been able to analyze and prioritize climate adaptation and mitigation technologies in the agriculture, forestry water and energy sectors. The process has also helped the country to develop the means of tracking its evolving needs for new equipment, techniques, practical knowledge and skills. During the process, the barriers that hinder successful deployment and diffusion of the prioritized technologies and the attendant frameworks that can enable removal of the barriers were analysed. The process concluded with the development of technology action plans (TAPs) whose outcomes are used to guide national dialogue with policy makers and investors.

To better understand how climate technologies identified through the TNA process can be practically implemented, an innovation systems approach is adopted, where actors that cause innovations to happen are identified and their respective roles and how they interact are analysed[vii]. Building on the results of the recently concluded TNA exercise in Uganda, and the available literature, we identify some of the road signs for and roadblocks to scaling up climate technologies in Uganda. The multi-criteria analysis that was employed during the TNA to identify the best technology options under the energy sector ranked rooftop solar systems highest in the energy sector and rooftop water harvesting as the technology of priority in the water sector.

Uganda, like most developing countries, needs to utilize adequate clean energy technologies for its development and to mitigate the impacts of climate change. However, these technologies are not adequately deployed and are therefore inefficient due to barriers (roadblocks) that have been identified as constraints to their transfer and adoption. Taking clean energy rooftop solar systems as a case study, we explore barriers (roadblocks) that hinder the transfer and adoption of the technology as well as elements of an enabling framework that can help Uganda overcome the barriers.

Case study 1: Rooftop solar PV systems

Solar rooftop systems are developed based on photovoltaic (PV) technologies and integrated with DC-electricity-based appliances. It is the most suitable technology used in remote and underserved off-grid and rural areas[viii]. While the Government of Uganda has made significant efforts to increase hydroelectric generation capacity and to extend the hydroelectric power grid to various parts of the country, the cost of grid-based supply is still too high for the majority of low-income households. This section of the society therefore needs alternative sources of energy. The solar rooftop market in Uganda is regarded as one that provides a significant investment opportunity for commercially driven solar PV business. Indeed, there are a number of local and international providers of solar rooftop systems across the country, especially in rural communities. The solar rooftop sector includes different business models such as ones where a consumer can purchase a system with an upfront payment. Others use a "*Pay as You Go*" system where customers pay a small amount of money to the vendor/distributor at regular intervals for an agreed period of time. This model has solved the challenge of high upfront investment costs for the technology. However, despite the availability of such flexible business models, scaling up the solar rooftop market still faces a number of roadblocks, some of which are discussed below.

Implementation barriers

Reliance on imported technology

Currently, Uganda does not manufacture any significant components of solar technology, nearly all the components of the technology is imported.

Low purchasing power

The income of farmers, rural businesses and labourers are uncertain and unpredictable due to seasonal weather variations that impact many economic activities such as farm yields, buying habits and labour hiring sequences and frequencies throughout the year. These categories of Ugandan society often suffer frequent income shortages and stresses, making their financial planning throughout the year difficult since their income is unsteady. These uncertainties affect their decisions whether to purchase solar energy equipment or not. Whereas the country's energy sector aspiration is to meet the energy needs of Uganda's population for social and economic development in an environmentally sustainable manner, the greatest question and challenge is how the energy needs of all Ugandans can be met in an environmentally sustainable manner, taking into account all social and income classes.

High upfront investment costs.
Rooftop solar PV technology comes with high initial costs. Similarly, at current price regimes, advanced solar energy technologies are still unaffordable to the majority of Ugandans. There is therefore need to make the cost bearable by spreading it over time through soft-loans, credit schemes or hire purchase schemes. Spreading the cost over a period of time would have the effect of making solar equipment affordable to low-income households. Incentives such as a comprehensive tax waiver on all solar accessories could enhance deployment of the technology. Effective linkages with micro-finance institutions to provide soft loans (credit) to clients interested in purchasing solar equipment would make the rooftop solar technology more affordable.

Lack of affordable credit
Although banks and micro-finance institutions in some parts of the country offer credit facilities for purchase of solar equipment, their terms are often unfavourable to clients, leading to low levels of financial and technology uptake. Awareness about the existence of such credit facilities is also low among the public. The high interest rates charged on the loans provided by these financial institutions deter the would-be borrowers. In an effort to promote the adoption of solar technology government has provided tax waivers on solar panels in a bid of making them affordable. However, good quality solar systems remain rather expensive, because the waivers do not cover the other associated accessories such as batteries and bulbs.

Low quality products
Several counterfeit solar goods of very poor quality exist on the market. These undermine public confidence in the quality of the technology and consequently suppress sales and marketing of solar equipment. An effective mechanism to check the entry of counterfeits into the country is necessary as the sale of substandard counterfeit solar products affects the marketing of genuine solar products.

Limited utility of rooftop solar systems
Smaller rooftop systems cannot power appliances such as an electric kettle with higher energy requirements.

Theft of solar panels scares off some potential customers
Reported thefts of installed solar system discourage consumers. This risk could be mitigated through use of ICT, serialization of parts, insurance or providing other forms of security of the solar panels and accessories. However, this has the effect of driving up costs.

Limited capacity
Solar technology vendors and technicians are mainly based in urban areas, quite far from their rural clients. This makes it difficult for clients to access the technology and prompt after-sales services. There is need to build additional technical and professional capacity in the country in the fabrication, installation and maintenance of solar equipment. Limited business management skills, technical and institutional capacity and as well as poor enforcement of standards and quality pose serious roadblocks to the transfer and adoption of solar technology.

Case study 2: Rooftop Rainwater Harvesting (RWH)

The technology needs assessment identified rooftop rainwater harvesting (RWH) as the priority adaptation technology in the Ugandan water sector. With an average rainfall of 500-1180 mm a year, RWH could potentially supply many rural families with water for domestic use and production, principally livestock watering or irrigation but its adoption is still low.[ix]

RWH technology entails collecting runoff water from a roof surface and storing it in above or ground tanks for domestic use and productive activities.[x] Rainwater can also be harvested by using technologies that involve using the soil as a storage and diverting runoff directly into the fields through trenches, ditches and bunds.

It can also be used to supply educational institutions, health facilities, offices and prisons. Stored rainwater provides opportunities for households to have direct control of their own water supply without the need for investing in energy and water purification chemicals. A basic rooftop rainwater harvesting unit consists of a roof surface, a storage tank, gutters, pipes and tap fittings, as well as filters and waterproofing agents. Hard roof surfaces which constitute 70%

of the urban houses and about 65% of the rural houses in Uganda[xi] are considered to be the most efficient in rainwater collection. Rainwater harvesting systems vary in scales and sizes. Tanks for rainwater storage can be ready-made or built on the surface. They can also be underground or partially buried. They can be made from plastic, tarpaulin, polyfibre, mortar, interlocking stabilized bricks, or corrugated iron sheets. However, a number of financial and non-financial barriers pose significant roadblocks to the transfer and diffusion of rooftop rainwater harvesting technology.

In their study on why householders in central Uganda do, and do not, adopt RWH, Chad et al.,[xii] found that the work of intermediary organizations, finance mechanisms, life course dynamics and land tenure were the three most important factors. They maintained that better understanding of these factors should inform government policy and the activities of development NGOs in Uganda and elsewhere in the developing world.

Economic and financial barriers to rooftop rainwater harvesting

Low private investment

Private investment is one of the key vehicles for facilitating wide diffusion of rooftop rainwater harvesting, that can increase the resilience of households to water scarcity caused by increasingly unpredictable rainfall. However, private sector investments that could satisfy this demand is still rather rudimentary. Private investment in water storage tanks, construction, vending ready-made tanks, downpipes and associated accessories such as guttering and plumbing fixtures, are equally low. This results in a scarcity of parts and supplies for RWH in the country, compounded by the low capacity of rural households to afford built-in RWH of sufficient capacity to satisfy their water needs. In 2017 there were approximately 21,000 rainwater harvesting tanks serving 126,000 people in Uganda, representing approximately 1 percent of the rural population.

The biggest financial cost of RWH is related to the storage tanks, which vary according to the type of materials used and the storage capacity. Although there is vast potential to harvest large volumes of rooftop rainwater, this is rarely achieved because of the inability of the household to invest in large storage capacity. Indeed, RWH technology vendors in rural areas prefer to supply tanks with a storage capacity of less than 250 litres because that is the capacity that is affordable to most rural households. It is mainly the urban consumers and better resourced households who can afford water storage tanks of 500 litres or more.[xiii] However, most of these affordable storage sizes do not satisfy full annual household water needs. Moreover, many households are not aware of the available RWH technologies in respect of material used, designs, construction techniques, and associated accessories, construction services and costs. For example, below-ground plastic-lined tanks are cheaper and could offer rural households larger storage capacity, but this is not widely known. Technology accessories such as first flush diverters for improving water quality and pumps are also not widely known. Creating awareness for RWH as a source of water supply has, historically, been given low priority and low budget allocation at planning and policy levels.[xiv]

Tank providers include wholesalers in towns, intermediary re-sellers in trading centres and retailers who avail products in 'last mile' distribution points.[viii] The more distant rural consumers have a lower capacity to afford RWH storage tanks thus resellers do not have the opportunity to offer product differentiation or additional value such as delivery or after-sales services for a price mark-up, making the business less attractive.

In order to bolster the adoption of the RWH technology, the Ugandan government and other non-state actors provided 100% subsidies in the 1990s to catalyse adoption, covering up to 90% of the costs for communal facilities and 30% for household facilities.[viii, xv] This approach was gradually changed over time, having a negative impact because it greatly weakened the demand from a privately driven market and stifled private investment in the technology, disrupting the market. Given that subsidized programs require a nominal contribution from the communities, ownership of the setups has been low and demand was not catalysed.[viii]

Non-financial barriers

Inadequate policy and legal instruments

Under the national water policy 1999, the government committed to supply clean and safe water for all.[xvi] Indeed, the policy puts RWH in a special category. However, government commitment only goes as far as demonstrating and creating an enabling environment. This is premised on the assumption that households are capable of using their resources to undertake rainwater harvesting and ensure self-supply.[xvii] However, this has not been the case. In fact, some of the interventions such as subsidies have instead become disincentives for the transfer and diffusion of RWH technologies, as discussed above.

Land rights and gender equity are also crucial factors in facilitating investment in RWH. Baiyegunhi[xviii] (2015) found that women whose land rights are insecure were 3.5 times less likely to invest in RWH than men. His analysis demonstrated a positive correlation between land ownership and the adoption of RWH technologies. The structures that are meant to support the promotion and monitoring of rooftop RWH technology are rudimentary and poorly supported. District water offices and officers as well as the community development officers at the local government, are not sufficiently resourced to implement and monitor RWH interventions.

Weak structures also constrain the enforcement of requirements of all government buildings, offices, schools, hospitals, and prisons which are required to have RWH storage. Awareness creation and sensitization, crucial in the promotion of RWH, neither receive sufficient budget nor get adequate emphasis at both planning and policy levels.[xiii] A study of the potential of rainwater harvesting as an appropriate technology for water supply in peri-urban areas in Uganda found that over 90% of the participants did not have any knowledge about the existence of policies on rainwater harvesting.[xix] There is limited knowledge about rainwater harvesting (especially on technology types, costs and impact of RWH) at community and household levels.

Inadequate extension advisory capacity

The extension system in Uganda is weak because of under-staffing and inadequate resources. Moreover, personnel lack training in RWH skills. RWH technology is generally considered to be too basic to require special skills and not worth including in courses offered in regular curriculum of training institutions.[xx] This has stifled investment in research and innovation to build it up as a key water supply strategy. The local artisans who are trained to set up RWH by NGOs and government projects find limited demand for their services. Those whose services are demanded are unable to serve wide areas due to limited accessibility and inadequate skills in relation to appropriateness and standards of training.[xxii, x, xxi]

The training provided tends to be generic in nature and does not provide options that are suitable to the diverse nature of rural households. For instance, a training that focusses on high-storage capacity RWH systems in supported 'demonstrations' makes the system appear complex and inappropriate for rural households. While skills and incentives that motivate private sector uptake of RWH technology are also generally lacking. In many instances, government and NGO projects start RWH projects without the involvement of the actor whom they expect to take over once the project ends.

Perceived low socio-cultural value of RWH technologies

Rural houses with hard roof surfaces rarely have the requisite technologies such as guttering and pipes that are necessary to direct the flow of water during rainfall. Because water is harvested using rudimentary methods, there is limited knowledge about the potential of RWH technology and so it is often disregarded. In Uganda, communities take the cycles of water abundance and scarcity as a way of life that does not require any intervention. The willingness to invest in RWH is low because potential users do not consider the range of options it enables nor the alternative costs of labour, time and risks incurred by women and children in supplying domestic water needs.[xxi]

Subsidies provided by government and NGOs have created consumer expectation of continued access to subsidized RWH technology. This has had the effect of limiting the willingness of private consumers to invest in self-supply. The scarcity of spare parts, poor extension services and lack of skilled maintenance personnel in rural setting has eroded confidence in the quality and longevity of water storage options.

There is limited demand for rainwater-harvesting equipment due to a generally low value attached to investment in water availability.[viii, x, xxii] This could be attributed to the fact that household investment decisions are mostly led by men with minimal participation from women and yet men largely have no direct roles in ensuring water availability at household level.[xxiii] The social norm of viewing and sharing water as a common good is also a disincentive to investment in RWH by the community because the one who invests rarely has the opportunity to recoup the cost or benefits directly.[xii]

Measures for addressing key barriers

Enable functional private sector engagement

It is important that different income segments and the local communities are engaged in technology promotion through demonstration and piloting, in order to identify barriers and solutions in each setting. Constraints in the supply of equipment and work force often leads to very high costs of acquisition, setting up and operating RWH that can be addressed through strategic engagement between government, the private sector players and NGOs. Such an engagement can provide opportunities to tackle key issues including subsidies, the provision of incentives through removal of tax duties on imported equipment and accessories. This partnership would also help stakeholders to identify business models that are appropriate for rural communities. The demand for technologies through private installation of RWH can be stimulated through training of consumers on the benefits of improved access to safe water. The challenge of inadequate supply of parts required for construction and maintenance of storage tanks could be addressed through strengthening the capacity for local innovation in fabrication.[xxiv] Finally, training institutions should have provisions for in-service training through which technicians who are already in the field can have refresher training and acquire relevant business skills.

Improve household access to financing

Access to affordable capital is a key constraint in the adoption of the RWH. This can be addressed by providing favourable financial support to rural households to enable them to pay for RWH installations. Local savings and credit schemes and innovations like revolving funds could be strengthened and used as sources of credit for low-income rural households to access finance required for upfront investment in RWH. Funding sustainability can be bolstered by enhancing the local economic base and livelihoods of potential RWH users through strengthening income generation options including high production and marketing of value crops. Gender disparities in access to and control of RWH installations need to be addressed to increase adoption of the technology, especially by women.

Strengthen technical capacity

It is necessary to develop a comprehensive RWH curriculum and job structures that facilitate placement of qualified technical personnel at local government level. The training of rural masons, technicians, households and communities in RWH is needed in order to increase availability of skills for RWH maintenance at the rural community levels.[xii] Districts need to be equipped with trainers in RWH technology installation, operations and maintenance. All these need to be supported with increased capacity in marketing, accounting, and management skills.

Strengthen community organization

In order to reduce or share the set-up costs for RWH, adjacent households with small roof surface area could pool resources and build shared storage. Traditionally, farmer groups are not organized around water needs. However, given the rise in water scarcity, groups can be guided to include RWH as a key focus area. Farmers can be provided with information and sensitized about the imminent dangers of climate change. This approach can then be leveraged to galvanize the formation of farmer groups around their water needs. Communities can be provided with guidelines to organize themselves for RWH. Water investment plans ought to be developed using a participatory approach where men are sensitized on the importance of providing water at household level while women are involved in the selection of options that are optimal to them.[xxv] Water officers in local government can focus on low-income households using a step-wise approach of starting with small volumes of water storage and gradually building up to sufficient quantity overtime.[xi]

Develop a catalogue/database of information on RWH technology

Access to information about rainwater harvesting by various communities can be promoted through the wide translation and promotion of the existing rainwater harvesting guideline into different languages. This would promote the understanding of technical details for the construction and design of options for different household sizes, material and associated accessories articulated in the guideline. Communities need to have access to RWH catalogues where they can get information on complementary accessories and equipment for water quality improvement as well as a database on prices of the different designs and contacts of service providers. The catalogue can also provide special information for areas with specific RWH conditions such as the cattle corridor.[xi, xxvi]

Strengthen coordination for implementation of RWH policy provisions

Government and partners who promote the transfer of RWH technology ought to ensure that their activities are well coordinated to avoid neglect of other areas while oversupplying others with the technology. There is need for the water and agricultural sectors to work closely and harmonise their planning and regulatory processes in order to realize the full potential of harvesting water for domestic use and agricultural production.[xxi, xvii, x] Gender equity and inclusion must be considered by all the key players in RWH if the transfer of the technologies is to be realized, at sufficient scale.[xxviii]

Demonstrate the value of RWH under different climate scenarios

Finally, it is important that target communities are well informed about climate change. This could be done by presenting projected climate scenarios and creating awareness of the potential socio-economic benefits of investing in RWH. This includes the reduced cost of moving long distances to fetch water and the time made available for children to engage in school and women to pursue productive, income-generating, activities.

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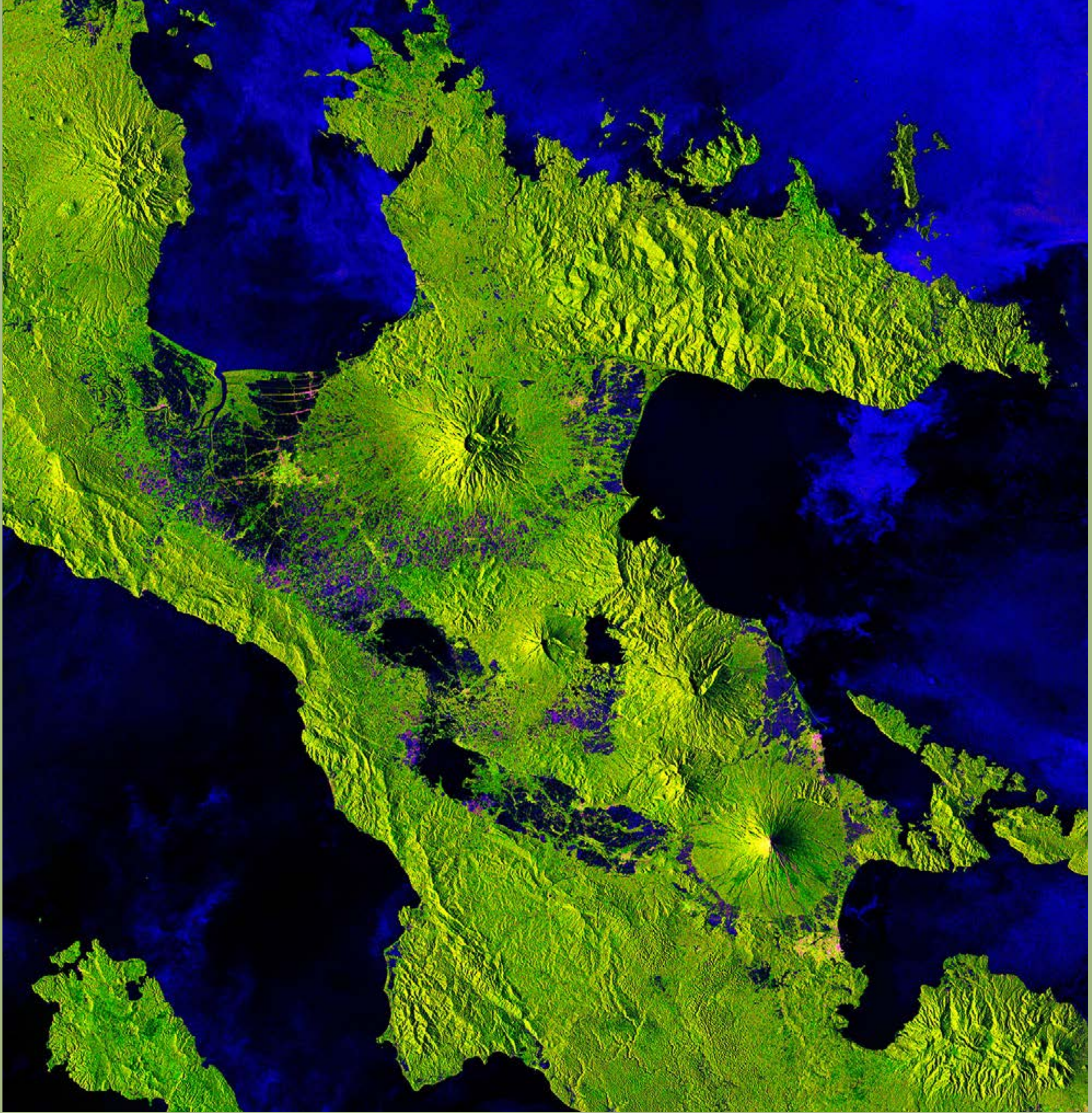

Mount Mayon in the Philippines, take by Sentinel 1-B. Photo credit: European Space Agency (ESA)

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EU Copernicus Infrastructure and technologies enabling the design and implementation of NDCs[1]

Abstract

In this article, we discuss the EU Copernicus Infrastructure and technologies for Earth Observation, that provides unparalleled opportunities to track all aspects of sustainable development more effectively, enabling the design and implementation of public and private actions to achieve agreed ambitions, including NDCs to the Paris Agreement. This is achieved by providing a wide range of environmental information that is key to the effective planning and implementation of disaster preparedness, response, risk reduction, and climate change adaptation strategies linked to economic benefits. We discuss the added value of Earth Observation technologies to NDCs broadly, before focusing in more detail on the case of the Philippines, where the Government is prioritizing efforts to enhance capacities at national and local levels on the use of spatial data, in particular from Remote Sensing systems for the ultimate benefit of local communities. To this end, the EU Delegation to the Philippines is supporting a national capacity programme for the uptake of the European Copernicus Earth Observation Programme's data and information, to address the Philippine Government's core objectives of developing and leveraging Space Science & Technology applications to strengthen the nation's resilience to natural disasters and climate change.[1]

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Introduction

The 2030 Agenda for Sustainable Development, the Paris Agreement and underlining National Determined Contributions (NDCs) are all data-driven policy systems. Earth Observation (EO) technologies provides unparalleled opportunities to track all aspects of sustainable development, including climate change mitigation and adaptation, more effectively. EO refers to the use of remote observation platforms such as satellites, aircraft and unmanned aerial vehicles (UAV) to gather data about the Earth's condition, monitoring the atmosphere, land, marine and freshwater environments. These images and data are then processed and analysed, producing relevant information that can be used for multiple applications.

Satellite observation technologies constitute the majority of EO data, including imagery and other data can provide key information for a number of areas including urban and rural development and planning, agriculture, transport planning and monitoring, water resources provision and quality, energy and natural resource management and monitoring. Information originating from space assets (i.e. satellites, ground stations, etc.) has become increasingly critical for informing and enhancing situational awareness about globally interconnected crises, especially when it comes to disaster risk management and financial preparedness, in which early and reliable information is key in ensuring a timely and efficient response.[i]

Until a few years ago, data gathered through satellites was accessible only to technical experts. Thanks to programmes like Copernicus, the EU´s EO programme, today anyone can access data and information services produced by satellites and *in situ* sensors. The European Commission (EC), in coordination with the European Space Agency (ESA), EU Member States and the EU Agencies, manages Copernicus. The satellite and ground station infrastructure is developed and operated by the ESA, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and the European Environment Agency (EEA). The EU Member States, as well as third countries, and commercial providers also contribute to Copernicus through the provision of data.

Copernicus collects digital data through a set of EU-owned, dedicated satellites (called Sentinels) and contributing missions (existing commercial and public satellites), which provide complementary high-resolution data.[ii] The Copernicus Sentinel satellites have specifically been developed by the ESA for the programme. There are six different satellite missions: Sentinel-1, -2, -3, -5P and -6 are dedicated satellites, while Sentinel-4 and -5 are payloads on board EUMETSAT's weather satellites. Copernicus couples satellite information with in situ data collected by Member States and international research infrastructures on the ground, at sea or in the air as well as model data. For instance, for air pollution monitoring, in addition to the satellite observations, there are more than 7,500 ground-based air quality measurement stations distributed across Europe used to both feed and validate the numerical atmospheric models of the atmosphere based on satellite observations. Copernicus Services then process and analyse satellite and in situ data, transforming them into value-added information.

Any individual or organisation around the world can access Copernicus data and Services on a free, full and open access basis.

Who are Copernicus users?

- Institutions and bodies of the EU
- Governments and public administrations
- The private sector
- Research and academic organisations
- International organisations
- NGOs and civil society
- General public

What is the added value that Earth Observation data can bring to NDCs?

Overall, data and information coming from EO are extremely relevant in informing NDC programming, coupling them with the sustainable development goals, in multiple fields. For example, satellite imagery can inform evidence-based public policies on urban development, climate change, health, agriculture, as well as disaster preparedness and response. It can also provide the data to support the development of a multitude of services and applications by the private sector. In parallel, EO technologies have the potential to enhance planning of future NDCs actions in the design phase, improve the efficiency of existing operations and activities, leading to better outputs and outcomes, and provide increased transparency, objectivity, and accountability in performing monitoring and evaluation.[iii]

Copernicus also offers the following benefits:

- **EO has global coverage**, including providing information on remote or conflict regions. The COVID-19 pandemic has highlighted that even if some areas are accessible in principle, they have been heavily affected by travel restrictions. Satellites collect information in all circumstances. Another example is that of the benefits that EO provides to authorities in monitoring severe weather events such as the recent tropical cyclone Harold in the Pacific, which affected communication systems, therefore limiting the information that could be obtained on the ground.[iv]

- **EO is objective**, which is particularly key to compare development indicators. Satellites collect data in the same way all over the world, thus ensuring transparency and objectivity.[iv]

- **EO is repeatable, continuous, and timely to acquire and process**. EO data are particularly useful in data-scarce countries, which are still in a development phase and can complement other sources of data such as census and surveys.

Copernicus technologies and services and their relevance for the NDCs

Raw EO data have no relevance *per se*, without the added value generated by enabling applications. Most final users require user-friendly information rather than raw data. Generating such information requires appropriate storage for the raw data and technical skills in processing and analysis. This is the reason why Copernicus services transform the raw data acquired by satellites into value-added information, by processing, analysing, and integrating them with other sources and validating the results.

There are six thematic Copernicus services:

Atmosphere
Climate Change
Marine Environment
Emergency Management
Land
Security

The different services deliver a mix of historical, near-real-time data and forecast products, through which final users can monitor changes, identify anomalies and obtain relevant statistical information to support institutional, research and commercial applications. The information provided by the six Copernicus services can be used to support NDCs design and implementation in specific sectors.

Examples of use cases in developing countries

Numerous are the programmes and projects, through which Copernicus technologies support the attainment of various SDGs, and the design and implementation of NDCs, especially of Least Developed Countries and SIDs, creating jobs and growth at the same time.

Examples of bilateral cooperation:

- Solar radiation maps from the **Copernicus Atmospheric Monitoring Service** (CAMS) have been used to explore water pumping with solar energy and to model solar powered cooking in Africa. Applications using the data are used to calculate expected financial returns for small and large solar energy projects.

- The Ghanaian Navy and the Ghana Fisheries Commission (Monitoring Control and Surveillance Division) are currently using the **Copernicus Marine Environment Monitoring Service** (CMEMS) for fisheries control.

- Copernicus Land products have been used to identify vulnerable areas and prime locations for species' reintroduction in West Africa and monitor the impact of conservation efforts.

- The **Copernicus Climate Change Service** (C3S) helps safeguard health, food and water security in South Africa by providing climate impact indicators and assessments that help adaptation to different climate change issues. During the Tropical Cyclone Kenneth that hit Mozambique in 2019 a number of mapping products were generated before and after the event to support national authorities.

- **In The Philippines**, Copernicus technologies and services are deployed for the creation of information products for CC mitigation (REDD+ reporting), vulnerability assessments for DRR/CC adaptation at provincial level and Marine Spatial Planning support to removal and monitoring of plastic waste in coastal and inland waters

Multi-country Programmes

In addition to bilateral cooperation, the European Union supports the development of Copernicus-based climate technologies and services for the design and implementation of NDCs via multi-country programmes such as GMES & Africa[2], ClimSA[3], SAWIDRA[4] as well as a number of Horizon 2020 such as AfriCultures[5] & TWIGA[6], expanded on below.

For capacity building, Copernicus offers a Massive Open Online Course (MOOC)[7] a free online training enabling users to understand how to use EO data for evidence-based public policy, as well as to develop new products and services, open up new markets, improve quality of life, and make the most of limited resources in a sustainable way. Participation in the *Copernicus Academy*[8] is another vehicle for capacity building. Interested organisations in developing countries can become *Copernicus Relays*[9].

The Copernicus Infrastructure and technologies generates daily over 12 Terabytes of Earth Observation open data, the third largest data provider in the world after Amazon and Google. With a free, full and open access policy, Copernicus is a global game changer in earth Observation, a domain traditionally reserved for governments, large companies and scientists.

Cases: TWIGA and AfriCultuReS

The **T**ransforming **W**ater, weather, and climate information through **I**n situ observations for **G**eo-services in **A**frica (TWIGA[10]) project and the Enhancing Food Security in **Afri**can Agri**Cultu**ral Systems with the support of **R**emote **S**ensing (AfriCultuReS[11]) build on progress made over the past decades in satellite-based EO, readily available through the EU Copernicus Infrastructure. In addition, these projects build on a network of 600+ TAHMO automatic weather stations installed in 23 countries in Africa, recent developments in low-cost meteorological (e.g. disdrometers, GNSS receivers etc.) and hydrological (ultrasonic water level, neutron detector etc.) sensors, UAVs (drones) and citizen science. These observation methods are well suited for the African, Caribbean and Pacific countries, given the extreme weather and lack of technical infrastructure and highly trained experts. The integration and assimilation of these multi-source, multi-scale data, together with satellite data with broad coverage, into simulation models, will produce new scalable geo-services for urban and rural end-users.

TWIGA and AfriCultuReS have developed technologies and services targeted at over 20 million Africans, starting in eight (8) countries: Mozambique, South Africa, Rwanda, Kenya, Uganda, Ethiopia, Niger, Tunisia and Ghana while building the capacity of African hydro-meteorological services and start-up companies with novel sensing methods and assimilation of in situ and satellite data. Target markets for TWIGA include Agriculture, Insurance, Water, Energy and Disaster Management, all very relevant for the African context. AfriCultuReS addresses the same markets, minus Energy.

The services developed in the TWIGA project include soil index insurance, crop yield estimation, crop stress monitoring, solar radiation forecasts, wind forecast for wind energy, land use monitoring, soil fertility monitoring, land degradation and erosion assessment, livestock heat stress monitoring, grazing and rangeland condition assessment and monitoring, water quality and quantity mapping, drainage and floodplain mapping, early warning systems for urban flooding, drought monitoring, biomass monitoring, weather forecast (localised short-term and seasonal) as well as disaster mapping (fires and floods). These services are being co-developed and offered with local start-ups and companies, thereby creating jobs and opportunities for youth and women. The delivery of these services is provided using agile platforms with Application Program Interface (API) endpoints, thus making them easily scalable and transformed into useable information in local languages, English, Swahili and French using SMS, IVRS, USSD, Apps, Dashboards (reports and analytics), print and mass media and making them gender-neutral. The raw data behind the services is available openly through GEOSS for further uses.

AfriCultuReS is dedicated to the sustainable increase of agricultural production in Africa, with special attention to risk reduction and adaptation to climate change. AfriCultuReS developed a portfolio that consists of seven services:

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2 http://gmes.africa-union.org/
3 https://www.climsa.org/
4 https://www.sawidra-acmad.org/en/
5 http://www.africultures.eu/
6 https://twiga-h2020.eu/
7 https://www.copernicus.eu/en/opportunities/education/copernicus-mooc
8 Copernicus Academy: https://www.copernicus.eu/en/opportunities/education/copernicus-academy
9 Copernicus Relays: https://www.copernicus.eu/en/opportunities/start-ups/copernicus-relays
10 https://twiga-h2020.eu/
11 http://www.africultures.eu/

- Climate: to improve climate predictions, seasonal climate early warning and climate adaptation advice;
- Crops: to improve crop condition monitoring and yield forecasts;
- Droughts: to improve drought early warning and forecasts;
- Land: to provide advice on avoiding land degradation and to improve soil condition assessment;
- Livestock: to improve grazing and rangeland monitoring, browsing capacity assessment and identification of available water sources for livestock;
- Water: to improve monitoring of water availability and productivity, crop water requirements assessment and soil moisture monitoring; and
- Weather: to improve (local) weather forecast and extreme weather events early warning.

The modalities of the services on offer are: mapping, monitoring, assessment, forecast and early warning. They make use of the following elements:

- Crop Models: developing agro-climatic indicators, seasonal yield forecasting, crop selection, crop suitability;
- Land Surface Models: land-use/cover change impacts on soil water and energy balance, log-term suitability, climate change adaptation;
- Hydrological Models: drought monitoring and seasonal drought forecasting, seasonal streamflow forecasting, integrated water resources management;
- Multidata Fusion: yield estimation, crop damage assessment, pest and disease monitoring and forecasting.

These models have been applied for the following crops: maize, wheat, rice, cassava, millet, sorghum, sugarcane and potatoes. Rangelands and pastures are another priority area for AfriCultuReS. In eight countries use cases are under development to introduce the AfriCulltuReS services.

Earth Observation data management and applications in the Philippines and ASEAN

High in the agenda of the Philippine Department of Science and Technology (DOST) is the enhancement of capacity at national and local levels on the use of spatial data, in particular from Remote Sensing systems for the ultimate benefit of local communities. The EU Delegation to the Philippines and the DOST jointly developed a national capacity programme for the uptake of the European Copernicus Earth Observation Programme's data and information to address the Philippine Government's core objectives of developing and leveraging Space Science and Technology applications, to strengthen the nation's resilience to natural disasters and climate change.

The cooperation envisages a future phase focused on enhanced high-speed digital connectivity between the Philippines and Europe as a driver to post-Covid 19 economic recovery and improved coordination of emergency response among the Association of Southeast Asian Nations (ASEAN) and in Asia Pacific region. Under the current phase of the cooperation the DOST and the EU initiate and shape technology transfer from global to local level, from Europe to the Philippines, and from the national technology hub at DOST to provincial and local authorities. The Philippines is a pioneer on Copernicus uptake in ASEAN. Advanced utilisation of Copernicus in the Philippines supports better policy definition, improved planning, increased transparency, commitment, and accountability. This ground-breaking cooperation paves the way for unlocking economic opportunities along with developmental and scientific co-benefits at regional level in Asia Pacific.

The context

The Philippines is the 9th most affected country in the world by natural hazards and climate variability according to the 2019 World Risk Report.[v] Up to 60% of the total land area in the Philippines is exposed to multiple natural hazards and 74% of the population is vulnerable to natural hazards impacts. The Philippines faces annual average losses of EUR 0.78 billion from earthquakes and EUR 2.4 billion from tropical cyclones and long-term climatic impacts or short-term weather extremes. According to the Global Climate Risk Index 2021[vi], countries like the Philippines that are currently affected by catastrophes continuously rank among the most affected countries both in the long-term index and in the index for the respective year as they were still in the process of recovering from the previous year's impacts. The Philippines is regularly exposed to tropical cyclones such as Bopha 2012, Hayan 2013 and Mangkhut 2018, due to its location.

The impact of tropical cyclones in 2019 and 2020 again sends a stark signal that knowledge about existing vulnerabilities and risk exposure remains a critical issue – even more so with climate change playing an increasing role in the intensity of tropical cyclones. Countries and communities that have been hit by cyclones are often left more vulnerable to other hazards and the impacts of climate change. To

Table 2. Operating models of Super ESCO examples

CRI 2000-2019 (1999-2018)	Country	CRI Score	Fatalities	Fatalities per 100.000 inhabitants	Losses in million US$ PPP	Losses per unit GDP in %	Number of events (2000-2019)
1 (1)	Puerto Rico	7.17	149.85	4.12	4149.98	3.66	24
2 (2)	Myanmar	10.00	7056.45	14.35	1512.11	0.80	57
3 (3)	Haiti	13.67	274.05	2.78	392.54	2.30	80
4 (4)	Philippines	18.17	859.35	0.93	3179.12	0.54	317
5 (14)	Mozambique	25.83	125.40	0.52	303.03	1.33	57
6 (20)	The Bahamas	27.67	5.35	1.56	426.88	3.81	13
7 (7)	Bangladesh	28.33	572.50	0.38	1860.04	0.41	185
8 (5)	Pakistan	29.00	502.45	0.30	3771.91	0.52	173
9 (8)	Thailand	29.83	137.75	0.21	7719.15	0.82	146
10 (9)	Nepal	31.33	217.15	0.82	233.06	0.39	191

Source: Germanwatch 2021[viii]

ensure better protection of the affected populations, adaptation measures and integrated risk management strategies are required to strengthen resilience that include the key steps of risk assessment, risk reduction, risk retention and transfer, preparedness, as well as response and recovery[vii].

Climate impacts, such as increasingly intense and frequent extreme weather events, affect people in developing countries disproportionately, threatening lives and livelihoods, human security, and sustainable development. These countries, and especially the most vulnerable parts of their population, have a lower coping capacity and are particularly exposed to the damaging effects of climate induced hazards.

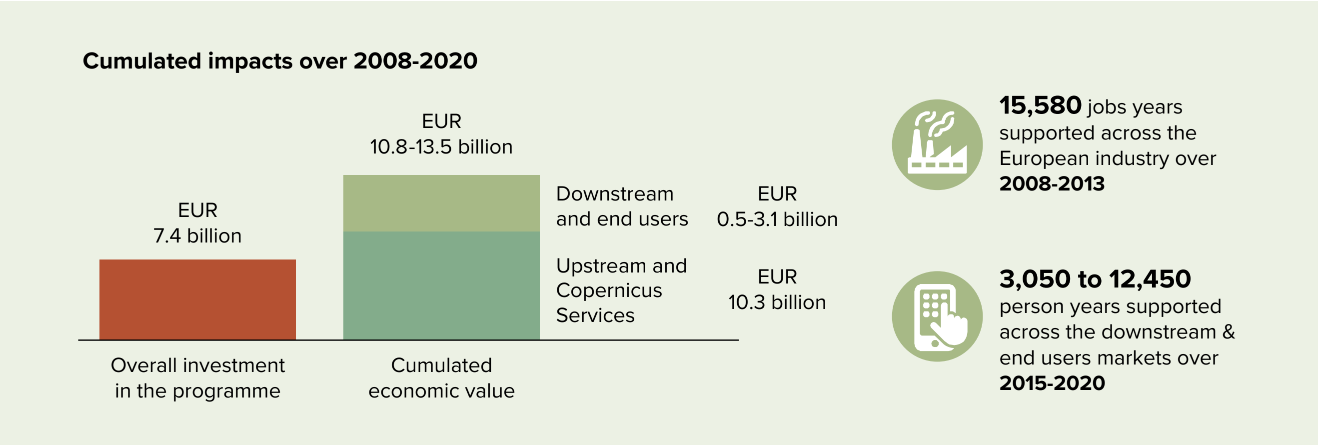
Concerning the design of interventions for improving resilience and to monitor their impact, the Sustainable Development Solutions Network has emphasized the role of often-neglected geo-spatial and geo-referenced data to disaggregate information for almost every proposed indicator – SDGs, climate change, disaster risk reduction.[ix] New sources and partnerships are critical to fill data gaps for existing and yet to be developed indicators, whereby it has been recognized that baseline geospatial data that should be provided by national agencies are often not accessible, not up-to-date or not available in standard format. Additionally, it is evident that effective decision making relies on accurate, up-to-date spatial information. More recently, the UN's SDG Report for 2020 surveyed the devastating impacts of the COVID-19 pandemic, highlighting the increased importance of "data innovations" to support sustainability goals by closing important gaps in data for monitoring and reporting on the SDG targets and indicators.[x]

European response

One of the EU's primary objectives is to support the onset of the green and digital transition both in Europe and partner countries by leveraging the digital transformation agenda as a growth model for a more sustainable, inclusive, and shock-resilient economy.

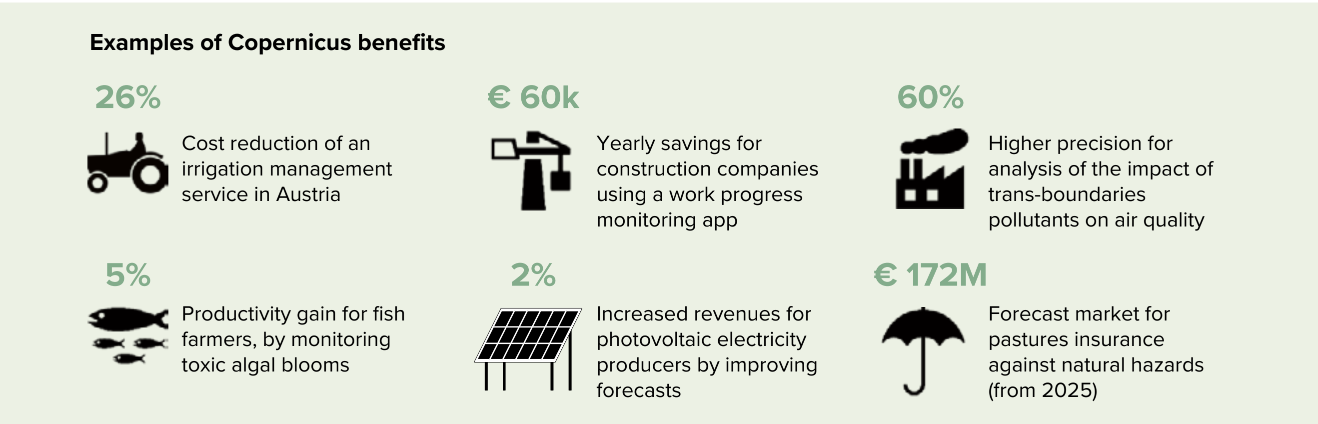
Digitalisation presents new tools for promoting circular economy, improving monitoring of deforestation and developing adaptation measures to reduce the impact of climate change and natural disasters. The selected sectors contribute to promote the international cooperation objectives of the European Green Deal[xi] and Digital Agenda.[xii] The Communication 'Shaping Europe's digital future'[xiii] in particular states that Europe as a global player will put in place a Digital for Development Hub D4D that will build and consolidate a whole-of-EU approach promoting EU values and mainstreaming digital technologies and services into EU Development Policy. The open, but proactive international approach outlined in the European Strategy for Data[xiv] will

Figur 1. Overview of the Copernicus programme's main economic impacts in the European Union



Source : EU-funded 'Report on the Copernicus downstream sector and user benefits' – PWC[xvi]

Figur 1. Examples of Copernicus' contributions to various projects and initiatives for selected value chains



Source : EU-funded 'Report on the Copernicus downstream sector and user benefits' – PWC[xvi]

guide the implementation, regulation, and maintenance of data infrastructures in partner countries.

The EU space agenda[xv], of which the EU Copernicus programme is an integral element, benefits the EU economy and society significantly, with revenues estimated to range between €120 and €195 billion over the next 20 years. These benefits reflect a 10 to 20-fold return on investment in Remote Sensing technology for Europe. With the use of space data in most sectors of the economy, more than 85 percent of these benefits are reaped outside of the space industry in key economic sectors (e.g. agriculture, fisheries, water resources, insurance, air quality, etc.). The graphic below provides an overview of the Copernicus programme's main economic impacts in the European Union. These have been quantified in both the upstream and downstream markets for EO, as well as in end consumer markets across eight value chains: agriculture, forestry, urban monitoring, insurance, ocean monitoring, oil and gas, renewable energy, and air quality. It is important to note, however, that areas of applications of EO and the benefits deriving from it go well beyond the limited selection presented.

It has been confirmed over the years that EO can unlock unique benefits for sustainable development, advancing the digital economy and scientific cooperation in several countries in and outside of Europe. Similar assessments such as the above-referenced study necessarily take into account the maturity of pre-existing IT infrastructures.

EU – Philippines Cooperation

Advancing the digital economy and connectivity is also one of the focus areas of the National Development Plan of the Philippine Government.[xvii] EO from satellite remote sensing, combined with modern data processing and enhanced analytics unlocks important benefits for better disaster management and offers unique opportunities to track all aspects of sustainable development. While major Government Departments which make use of spatial data have well-developed capabilities in a number of specialised fields, much IT infrastructure is insufficiently developed, with sub-optimal processing power, low-bandwidth communication lines, and a weak culture for data and information sharing. Combined, these factors limit the effectiveness of delivering essential evidence-based data for policy implementation and decision-making.

Mindful of potential developmental paybacks and the vulnerability of the Philippines to climate change impacts, the EU Delegation to the Philippines and DOST joined forces to develop a national capacity support programme on Copernicus.

Technology transfer concept

To ascertain the sustainability of the intervention, the cooperation on the transfer of technology – in this case earth observation and spatial data technology – has to be tailored to existing capacities and address key priorities of the partners. Leveraging satellite-based data and information for improved climate action in the Philippines, we followed a three-step approach:

- Assess the EO/Geoinformation (GI) Maturity of the Philippines
- Formulate an intervention (project) building on strengths and addressing weaknesses
- Securing the sustainability of the intervention by follow-up measures

Maturity assessment

The independent, up-to-date and replicable methodology for the assessment and monitoring of EO/GI maturity at national level, developed and further refined by two R&D projects, establishes an analytical tool that allows the quantitative measurement of the current EO/GI capabilities in a given country and their evolution over time.[xviii, xix] To that end, a set of indicators was defined across three main fields: "Capacities", "Cooperation" and "National Uptake and Awareness". For each of the indicators, a methodology was developed to allow the assessment of its maturity level. In parallel, a standardized process was established for the collection and analysis of the necessary data. This entails primary research by experts with deep involvement in national and international EO/GI activities, enhancement through publicly accessible data sources and a cross-validation of findings by renowned national experts. After analysing the collected data, the results are communicated as a standardised visualisation in the form of a "maturity card". The maturity cards have proven to be a powerful tool to highlight strengths and weaknesses, communicate on identified gaps, and understand the level of uptake of the technology.

The results of the assessment indicate that the Philippines rank overall on an intermediate to advanced level of maturity, by comparison with other countries (e.g. Serbia, Greece, Egypt) that have so far been assessed by using the same methodology.

Formulation of intervention

The formulation was based on (a) building on the Philippines' strong expertise in space technology applications (e.g. developing and operating its own satellite program), and (b) addressing weaknesses such as weak capacity for handling spatial data in institutions, lacking culture of data and information sharing, and low bandwidth connectivity.

The planned programme foresees an initial phase on utilisation of space science and technology applications to strengthen the country's national hazard management capability and disaster mitigation strategies. Through an integrated approach of Remote Sensing infrastructure development and capacity enhancement on Copernicus, a Phase I of the cooperation has been initiated in 2021. This promotes environmental sustainability and evidence-based decision-making for better planning and more efficient coordinated response to climate change impacts and other forms of natural disasters.

Four areas of support have been identified for the EU-based intervention, to enhance the hazard management and disaster mitigation strategy of the Philippine government, as well as ensure the nation's resilience to climate change:

- *Awareness* – The awareness about benefit and limitations of EO derived information is continuously improved

- *Data infrastructure* – Sentinel data are readily accessible for all users in the Philippines (Mirror Site)
- *Uptake of data & information* – The operational uptake of Copernicus data and information in key areas of national interest is demonstrated:
  · Improve environmental management – REDD+
  · Strengthen resilience to natural hazards and climate change
  · Marine Spatial Planning
- *Skills development* – EO/GI skills and knowledge are strengthened through exchange of experts and relevant academic programs

Securing the sustainability
Phase II of the cooperation is currently under preparation as an extended component of Phase I under the EU 'Team Europe Initiative' (TEI).[xx] Team Europe is a new form of cooperation between the European Commission, EU Member States and partner countries, which aims to address cooperation in several areas of post-Covid 19 recovery. The TEI approach will leverage on the achievement of Phase I of the cooperation on Copernicus in the Philippines, to address key challenges of post-pandemic recovery through digital transformation and enhanced connectivity nationally and regionally. In the specific context of Copernicus TEI will reap the full benefits of a Copernicus Cooperation Arrangement[xxi] between the EU and the Philippines and with a number of prospective countries in the region. These international agreements of which the Philippines will be at the forefront in ASEAN will be key to support the uptake of EO technology in national policies as a key instrument for better planning towards natural emergencies and recovery responses including pandemics, transboundary environmental challenges, climate change and consequent economic shocks.

High-speed Remote Sensing data delivery, exchange and processing capacities developed under Phase II will bring ASEAN and Europe closer together. It will allow the Philippines and neighbouring countries to obtain data and information from the Copernicus Services in real time to be tailor-processed in-country for specific priority applications. At the same time, the EU will reap benefits of real-time access to land, marine and atmospheric data to improve the accuracy of climate models for Europe, including modelling the evolution and impacts of El-Niño events under climate change scenarios.

The ramifications of data from enhanced capacity on Earth Observation are important and go beyond environment-related domains. This necessitates advanced data collection architectures, cutting-edge data mining and modelling, high-tech IT connectivity, development of data centres, and qualified professional personnel. The implementation of technological innovation on its own brings prosperity, employment, and modernisation, as well as the development of digital infrastructures that can be used in a variety of other industries and businesses.

Against this setting, a national Mirror Site[12] for the Philippines is to be established in Manila under Phase I of the cooperation. This will be operated by the DOST and the recently established Philippine Space Agency (PhilSA), to be upscaled under Phase II to a regional Mirror Site facilitating access to Copernicus data and development of applications, products and services for Government authorities and stakeholders in ASEAN and Asia Pacific.

For this to be realised existing high-speed connection capacity of the Philippines from-to Europe and, between the Philippines and ASEAN neighbouring countries will be enhanced through the phased financing of dedicated Indefeasible Right of Use (IRUs) on existing and presently developed fiber optic submarine cables linking the Philippines with the Trans-Eurasia Information Network (TEIN) in mainland Asia. TEIN is the world's largest science and education network, which provides Asia-Pacific science and education groups with dedicated high-capacity Internet access. TEIN[xxii] also contributes to the GÉANT[xxiii] network's 40 million European researchers and scholars and facilitates joint programmes with Europe in fields including Earth monitoring, climate research, food security, e-health, and e-learning.

The dedicated high-speed link will bolster relations between the Philippines, ASEAN, and Europe. It will allow a widespread and integrated use of Copernicus satellite data for disaster management and climate change response by allowing a much larger volume of Earth Observation environmental data and information to be processed and exchanged in real time. It will also boost education, research, and innovation while enabling businesses and companies to benefit from a high-security dedicated connection with Europe to

[12] A Copernicus Mirror Site is a data access point serving satellite data from Sentinel satellites over a specific country or region for users and organizations that want fast access to these data

further develop a digital data economy. Improved high-speed connectivity between Europe and the Asia Pacific region, initiated by the pioneer EU-Philippines Copernicus partnership, will also hasten the evolution of new business sectors for Earth Observation SMEs in cooperation with European partners, creating enormous economic potential and significant job opportunities for young professionals.

Analogous to the Innovation Hubs defined under the Digital Agenda for Europe, Copernicus Knowledge and Innovation Hubs (virtual/regional)[xiv] will be established to boost user uptake and development of information services using the free, open, and full access satellite data provided by the Copernicus Mirror site. This will facilitate an effective transfer of knowledge, encourage cooperation, explore synergies, and increase targeted capacity building and training provision in support of local authorities, private sector companies, and civil society organisations to reduce the vulnerability of communities at risk. The development of these hubs could be supported by the Digital Connectivity Fund envisaged under the international partnerships for the digital decade proposed by the EC 2030 Digital Compass: the European way for the Digital Decade.[xxv]

The ongoing cooperation is therefore crucial not only for the future growth of Copernicus Services in the region and the huge economic benefits that this will entail and unlock. But as a free and full access programme, Copernicus has unique potentials to stimulate innovation for a better response to the challenges of climate change in the highly vulnerable ASEAN region with the added benefit of new political options for enhancing EU-Philippines and EU-ASEAN relations.

Conclusion

Earth Observation technologies offer significant benefits that can unlock important opportunities to track all aspects of sustainable development. EO data allow more accurate comparisons across countries/regions or complex analysis of findings over a single location as opposed to conventional approaches which often suffer from lack of standardisation of measuring methods, different statistical methodologies, and lack of accuracy over time. The EU Copernicus programme is designed and operated to maintain a consistent flow of acquisitions and records, allowing government agencies to design, prioritise and implement reliable monitoring policies while enabling enterprises, public utilities and related services to expand over time. The economic gains that Copernicus provides to the EU is an illustration of the programme as an important engine for the advancement of the digital economy and sustainable national and regional economic growth.

Based on the free and open Copernicus programme, a cooperation has been forged between the European Union and the Government of the Philippines seeking to deepen the common understanding of complex Earth systems and human dynamics interplay across different disciplines and underpinning technology-based policies and strategies for sustainable development and economic growth. Through this cooperation, partners seek to build knowledge and capacity on environmental and human aspects of local, regional and global change through a blend of scientific research and technology-based enabling investments.

A Maturity Assessment conducted to guide choice, viability and meaningful utilisation of space-based technology applications in the Philippines provided the foundation for the formulation of the various components of the cooperation under which relevant interventions and realistically implementable applications were defined. The cooperation will be building on an already adequate knowledge base and technical milieu on disaster risk management and spatial data analysis in the Philippines - more advanced than in many other developing countries. This is not surprising given that the Philippines has to respond effectively to all kinds of natural disasters – climate and non-climate related.

The multi-dimensional aspect of adaptation to climate change and its inextricable links to economic health and political stability can draw significant benefits from EO. Customized EO applications for modelling ocean- and land-use change related climate impacts are showcase areas of Copernicus that the partners will jointly implement under the cooperation project. The development of a modular Copernicus mirror site for the ASEAN region and customisation of Copernicus Climate[xxvi] and Maritime Monitoring Services[xxvii] to the regional context will support climate change policies and adaptation strategies strengthening national and regional resilience to future shocks in compliance with the EU's external action strategy.[xxviii]

Through ease of access to data and value-added information from the free and open Copernicus Programme, a more progressive data sharing culture will be initiated nationally and regionally. This facilitates evidence-based policy definition, transparency, accountability, and continuous monitoring, whether in the context of specific SDGs or progress of the Philippines and its ASEAN neighbours towards NDC targets. The initiative has a high potential to evolve into a global replicable concept transferable to other regions of the world.

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The power of bottom-up and multi-stakeholder approaches to improving the uptake of sustainable household energy technologies in non-OECD economies

Abstract

Energy efficiency and renewable energy technologies in households have a key role for the achievement of the Paris Agreement and to contribute to various SDGs. In pursuit of these objectives, multilateral funds, in conjunction with local governments, design and implement different technology transfer policies. However, the results are very different. In this article we explore recent cases of energy policies to increase the use of renewable and energy efficiency technologies and practices in households in some countries of Latin America, with the aim to identify the key means to closing the gap between technology needs and implementation. We identify two key aspects that determine the impact and result of technology uptake: the elaboration of policies with a bottom-up and multi-stakeholder perspective. With this in mind, we offer some policy recommendations.

Introduction

Energy efficiency and renewable energy technologies in households have a key role in achieving the Paris Agreement goals and the clean energy transition, with significant co-benefits for socioeconomic development, especially for developing regions. However, there is a significant unrealised potential in household energy efficiency measures, across the world. This means that the amount of energy used to fulfil different energy services (e.g. heating, cooling, lighting, transportation, producing goods) could, and should, be lower than it is today. Similarly, there is still a huge potential to increase the use of renewable energy technologies at the household level.

In order to close these gaps, multilateral funds, in conjunction with local governments, have to convert the political rhetoric on the transfer of clean or environmentally sound technologies (EST), into reality before 2030. Key to achieving this will be government-driven policies, based on a combination of push and pull instruments, to enable and incentivise investment at the household level. To date, the results of such actions have been mixed.

Within the academic and grey literature, there is a wide consensus regarding the importance of local context in determining the success, or not, of the policies implemented. There is a long list of boundaries or enabling conditions that may improve (or reduce) the technology capacity to penetrate local markets. For example, the existence of a latent demand for renewables or energy efficiency technologies that generates a suitable niche market and the capacity of technologies to meet an existing local need. It is equally important to understand the market conditions for this need to be satisfied by economic goods, the competitiveness of the technology and the payment capacity of the population. Other factors include the availability of other resources and goods which are necessary for the technology to meet a need, and the existence of technical and economic capacity to deploy the technology at national or regional level. These are some of the key issues that policy makers need to consider and address when designing national strategies to accelerate the uptake of household energy efficiency and renewable energy technologies.

Framed by these issues, we explore recent cases of energy policies to increase the use of renewable and energy efficiency technologies and practices in households in some countries of Latin America. In doing so we aim to identify the key aspects to close the gap between technology needs and implementation. Specifically, we aim to answer two questions:

1. What are the key aspects to be considered during the design phase?

2. Which of these aspects is most relevant in the implementation phase, to accelerate local technology adoption?

We attempt to answer these questions by reflecting on real-world case studies from across Latin America.

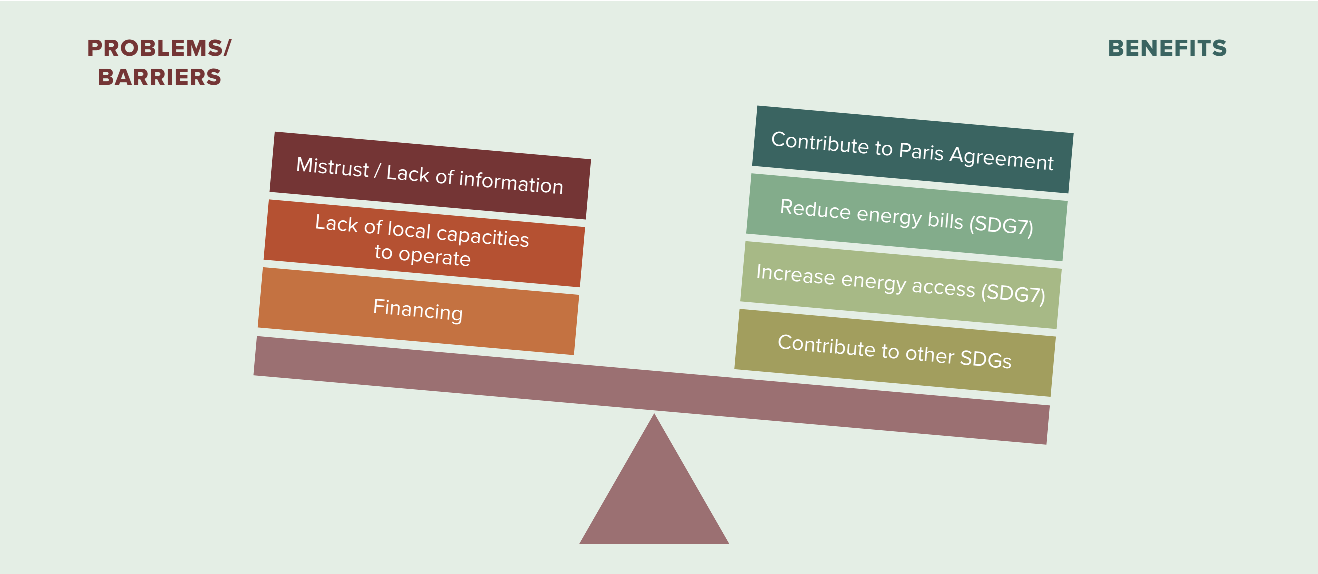
Household energy efficiency and renewable energy technologies: an opportunity for developing regions to meet the Paris Agreement and SDG7

The household sector accounts for the needs of private domestic consumers to meet different energy services, such as space heating and cooling, water heating, cooking, lighting, electricity for appliances, among others. All these services are crucial for individual welfare and development. Access to electricity and other modern energy sources improves health and education conditions, with the consequent impact on human capital, as well as direct welfare impacts from the financial cost of energy supply.

The household sector is one of the largest end-use sectors worldwide. Household energy consumption is driven by different variables, such as geography, weather, building structure, energy prices, appliances prices, availability of energy sources, cultural aspects, population growth, per capita and household income, among others.

Energy policies focused on the household sector in developing regions are very important, both for their contribution to Sustainable Development Goals (SDGs), and the contribution to the Paris Agreement objectives. Indeed, SDG7 states *"Ensure access to affordable, reliable, sustainable and modern energy for all"* by 2030, where energy efficiency actions, as well as renewable energy, have a clear impact. Renewable energy and energy efficiency may also be a good way to complement other SDGs in developing regions, such as SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 10 (Reducing Inequality), among others. Despite these clear benefits, technology uptake has been slow and erratic across

Figure 1. Barriers and benefits for renewable and energy efficiency technology adoption in developing regions



most developing countries, especially in Latin America, for diverse reasons that are important to explore.

A commonly cited definition of environmental technologies classifies them in terms of hardware, software and 'orgware', referring to the mix of material components, know-how and systems to manage technologies, once installed.[i] This is the case of medium to low-income households, in which actions related to the phasing-out of inefficient technologies and promotion of new efficient alternatives are as relevant as behavioural changes in using the technologies and resources.

For instance, in the case of the adoption of energy efficient technologies in households, in general, the most important barriers, particularly in low-income homes, are:[ii, iii, iv]

- Lack of access to modern energy sources
- Low-income households tend to live in old and low-quality buildings with low energy efficiency standards
- Lack of access to affordable finance for retro-fitting technologies, even if they offer short pay-back periods
- Energy efficiency is not seen as a priority given competing basic needs
- Most vulnerable and low-income communities have lower levels of trust in local authorities, policy makers, companies, and other stakeholders
- These homes usually do not have access to reliable information and knowledge required to evaluate the energy efficiency opportunities
- The frequent use of second-hand markets to purchase appliances
- Magnified perception of upfront costs in comparison to the cost of energy bills

Technology transfer strategies in low to medium income homes in developing regions need to be designed carefully, taking into consideration all these issues.

Designing interventions bottom-up

Challenges to the success of technology transfer in developing regions mostly emerge from a methodological perspective, in the design phase of the policy or intervention. Many strategies are conceived from a universal deterministic and top-down viewpoint, without considering the enabling conditions for technology implementation, diffusion, and uptake.

The universal deterministic point of view means extrapolating successful policies from one region or another, which usually fails. Top-down interventions tend to fail because they lack a careful evaluation of context and case particularities. This standpoint ignores the relevance of context (border) conditions. Either for energy and socioeconomic systems, as well as for the implementation of energy policies, both context and history influence the current and future outcomes and evolution. Energy services and energy demand in households, for instance, depend on environmental and geographical characteristics such as climate and geography, but also the economy, culture, habits, etc. There are numerous examples of otherwise successful experiences that have failed, when 'imported' top-down in the LAC region.

Ecuador's strategy to introduce induction stoves in low-income households is an example of this policy perspective and its results. Ecuador implemented a program with the aim of installing 3 million induction stoves. These stoves were installed in border areas, characterized by high LPG consumption levels and LPG smuggled to Colombia and Peru, as a result of the low price of this fuel in the country. Due to the lack of State control, commercial companies forced marketed induction stoves to low-income homes. The buyers incurred unpayable debts, in addition to heavy investments from the State, which had to extend the 220-volt distribution networks which, in some cases, a year after receiving the stoves, remained unused. Electricity bills in these households increased, in some cases up to ten times. Furthermore, even though the program was supposed to be a boost to the national industry, the stoves were imported from China at prices that were not competitive for the incipient national industry, with the opposite desired impact on the national economy. The failure of this policy was mainly due to the way it was designed, without considering all policy dimensions and local context.

A similar example of the failure of top-down policies can be found in the case of the GEF program to place 15,000 PV panels to provide electricity to isolated residents in the Peruvian Amazon, very close to the border with Ecuador. The project faced multiple difficulties and had to be abandoned due to the lack of a comprehensive evaluation of the location, socio-cultural realities and complexity of the technology. The main obstacles faced by the project, were, firstly, the selection of the region that was very difficult to access and very far from urban centres that could provide support to the users and with changing water courses. Secondly, most of the inhabitants of the region were nomadic, they abandoned their precarious dwellings when the rivers changed their course. Thirdly, all the equipment remained under the property of the State because of national regulations. This legal framework prevented the transfer of property to the users, and the State also had to take care of project maintenance costs (which were very high due to location). In short, only a few devices were installed, and the project could only be partially completed by choosing other regions of the country to install the equipment. Once again, an inadequate evaluation of reality and a geopolitical decision resulted in an unsuccessful and costly project.

There are also successful cases in which a technology is perfectly adopted, even without policy intervention. This is the case of the adoption of windmills for water pumping in the Argentine Humid Pampa. Argentina had natural resources to produce millions of cattle, which, in addition to rich pastures, required water that could be obtained from the ground, to support the beef export program to the United Kingdom. The technology to pump water was already known in the USA, since the 19th century. In this context, private actors began to import these mills from the USA, though they soon realised these machines were easy to manufacture. This kick-started a process of import substitution and technology improvement, where the mills began to be made of metal and gave rise to a new industrial and market niche. Simultaneously, in the small towns of the rural areas, a new opportunity arose and the development of skills, often in a totally self-taught way, of the so-called Molinero (miller). This last element implied a huge education and training strategy in a few decades that produced excellent results in very early times. This is an excellent example for the technology uptake without specific policies linked, thanks to a combination of elements: a product (meat) demand, that generated a derived demand, abundant natural resources to produce it in large quantities and the existence of technology that allowed access to one of the resources that the productive activity required. This was complemented by the existence of capacities to adapt, improve and disseminate the technology and, finally, the capacity to operate and maintain the technology in the dispersed places where it was located.

Top-down interventions are meant to fail in most of the cases, particularly for policies targeted at the household level. In contrast, bottom-up policies have proved to be more successful in many circumstances in developing countries. This, however, does not mean that learnt lessons are not useful, but they need to be adapted. For the case of renewable and energy efficiency technology in households this implies, at least: 1) a careful evaluation of the household demand, and the energy service that needs to be fulfilled; 2) the best technology option (hardware, software and orgware) to be used in the specific case, and 3) the barriers for the technology uptake. Steps 2 and 3 are the most relevant in terms of pursuing a bottom-up approach. In the case of technology selection, Franco et al. (2017)[v] and Schmukler

(2018)[vi] stress that socio-technical adequacy is extremely relevant for the local adaptation and incorporation of a technology. This means that the technology needs to adapt to the socio-demographic context in which it is transferred. This aspect, therefore, reveals the importance of local participation during the design process, avoiding a reliance on assumptions or ideas defined top-down. Then, during the implementation phase, flexibility is key. Technology adoption barriers are clearly case dependent, and so must be the policy instruments.

The value of multi-stakeholder perspectives: the role of local organizations to improve the design and impact of projects

Participants in technology transfer include not only those involved in the direct transactions (private firms, state-owned companies and individual consumers), but also many others who play important roles "behind the scenes" (financiers, aid agencies, national governments, international institutions and local community groups). Results are positive when all stakeholders communicate and actively participate. As stressed by UNEP, a multi-stakeholder partnership and the existence of local partners seems to be crucial to accelerate and consolidate changes in consumption patterns.

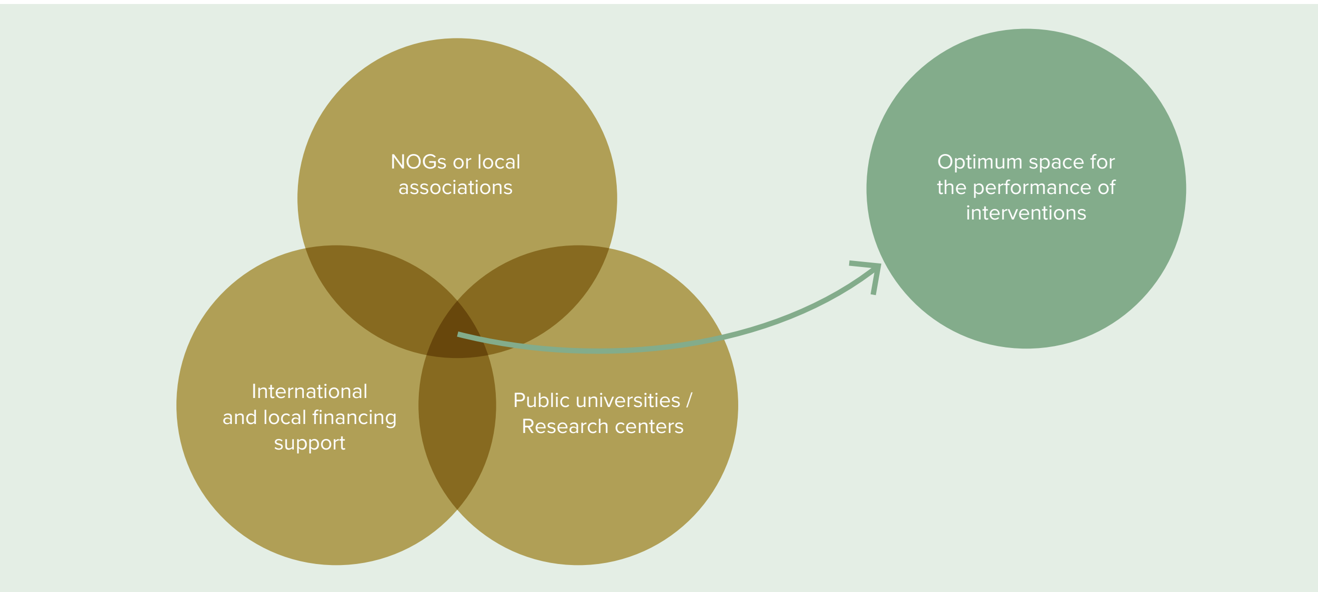
Figure 2 shows the best space for technology uptake at the household level during the implementation step. Firstly, interventions need to be designed, co-designed or/and implemented by local institutions /organizations with good knowledge of the local context. This aspect helps to remove the social barrier related to the low levels of trust in local authorities, policy makers, companies, and other stakeholders that implement the policies (which increases in the case of international interventions).

Secondly, the lack of access to reliable information and knowledge on energy technologies is a characteristic of many homes in developing regions. This barrier should be, mostly, addressed in advance to any other barrier. There is a significant amount of information delivered by international institutions or organizations (and even by national governmental departments), but this information does not always reach the target end users. An approach to tackle this problem is to provide specific capacity building programs during the transfer process. This key process could be developed by public universities, research centres or academic institutions. Thirdly, regarding the financial barrier, local and international funds may be needed. In this case, an alternative may be to establish a financing strategy with electricity and natural gas utilities, particularly in the case of energy efficiency actions.

A bottom-up and multi-stakeholder experience for energy efficiency actions in low and medium-income neighbourhoods in Argentina

There are numerous examples of projects designed by local organisations, bottom-up, offering valuable insights and

Figure 2. Strategies for involving diverse stakeholders and institutions



lessons. Here we focus on a recent Argentinean program to increase energy efficiency in low- and medium-income houses in the Metropolitan Area of Buenos Aires (AMBA in Spanish): Neighbourhood Energy Focal Points. This project, implemented by the Non-Governmental Organization (NGO) Fundación Pro Vivienda Social (FPVS in Spanish)[1] and the School of Science and Technology (ECyT in Spanish) of the Universidad Nacional de San Martin (UNSAM in Spanish), provides training to residents of the target neighbourhoods on how to manage their energy resources and adopt energy efficient practices. In words of Salvador Gil, director of Energy Engineering at UNSAM and project manager "…with efficient energy use (low-income homes) can also save the physical effort and transportation costs of buying firewood or LPG…".[vii, viii] Therefore, this project aims at reducing GHG emissions and improving quality of life. As such, the idea is to transfer knowledge about efficient managerial procedures on energy use to households in the lower-income category. To 2020, more than 15 neighbourhood leaders were trained, who have advised more than 100 households on how to save energy.

In this project, the neighbourhood energy focal points carry out energy audits, measure the consumption of all appliances in participating homes and identify the most important aspects of domestic energy consumption.[vii] The work has two key connected purposes:

1. To train students of the Energy Engineering career at UNSAM and related courses on how to conduct household energy audits and efficient energy management.

2. Train neighbourhood energy focal points through a program of virtual classes, where the participants were originally members of the FPS. The training focuses on carrying out energy diagnostics of homes in different neighbourhoods in the peripheral and marginal areas of the greater Buenos Aires – generally low-income – and provide guidelines for the efficient use of energy in their homes.

Based on these evaluations, the neighbourhood energy representatives provide practical advice on energy management actions that can be implemented by the households in order to reduce energy consumption. Some are very simple, other more complex, such as:[vi, vii]

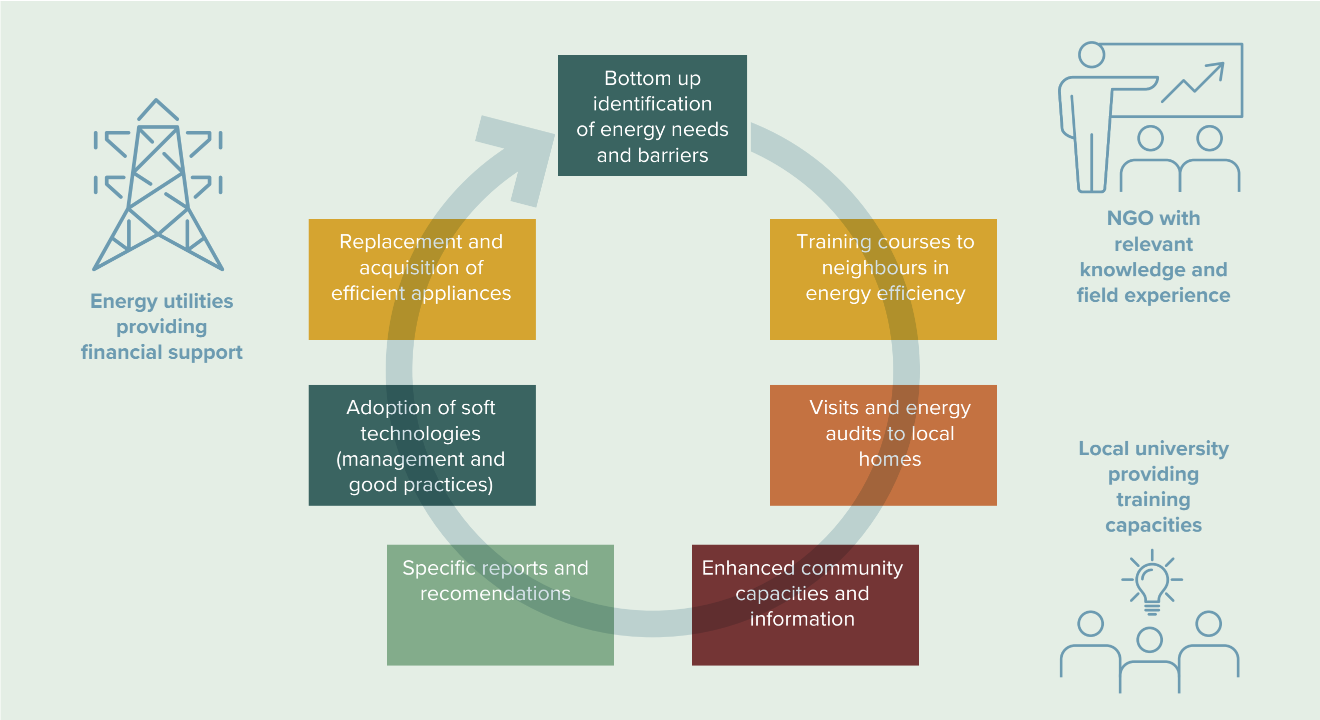
- Reduce air infiltrations, with carpenter's tape and nylon
- Regulate the heating and cooling temperature with a simple wall thermometer or by regulating the thermostats of some equipment
- Choose or opt for an adequate and efficient heating system
- Heating only the places that need it
- In refrigeration, use as much as possible evaporative fans and air conditioners, which consume 10% less than an air conditioner, especially when temperatures do not exceed 30 °C
- Purchase domestic hot water heating systems (DHW) with an energy efficiency label
- Choose refrigerators class A (or better) in energy efficiency
- Replace old light bulbs with LED technology

The last four actions mentioned focus on low-cost technology options (mostly managerial actions) need to be accompanied by more costly actions including the replacement of hardware and appliances, which may require additional supply-side support, where leadership from national Energy Authorities is needed.

A notable aspect about this experience in terms of technology transfer, is the integrated and inclusive approach in which it has been designed. In this case, this multi-stakeholder partnership has included the three dimensions mentioned in Figure 2. Firstly, the UNSAM, which provides most of the capacity building for the program. Secondly, as stressed by Gil (2020)[vi] the FPVS is a NGO that has been working for more than 20 years with low-income neighbourhoods in the AMBA. During that time, it has contributed not only to the construction of natural gas networks, which offer a more economical and reliable service, but also to the participation of neighbours in the laying of networks and internal installations. This experience was crucial to increase local acceptance. The participation of a NGO with longstanding experience in the region is very important to remove the barriers related to the confidence of the community, their willingness to engage with external stakeholders. Thirdly, the electricity utility, EDENOR, that has the local responsibility for electricity distribution in the area, provided financial and technical support. The participation of the electricity company in this type of project reflects their enlightened self-interest, as the efficient use of electricity among end users helps reduce distribution losses and

[1] http://fpvs.org/eficiencia-energetica/

Figure 3. Successful elements and stakeholders of the "Neighbourhood Energy Focal Points" project in the AMBA



increase the quality of supply, by minimising periods of peak demand.

A key aspect that seems to have increased the performance of the project is that it was built with a bottom-up perspective. Indeed, the idea of the project emerged from people with long-term experience in the local community, who are familiar with the real needs, information and capacities of the local households. This is extremely relevant, as many technology transfer experiences tend to fail due to low levels of community uptake, reflecting interventions designed top-down that fail to meet local needs and circumstances. As mentioned by Gil this project emerged from the existing knowledge of FPS in the area, which contacted the UNSAM to look for a way to reduce energy consumption in homes in these neighbourhoods, as a result both institutions created the training course for neighbourhood energy managers.

A third relevant aspect of this project is that it focuses on removing the information and capacity barriers prior to other interventions, which is commonly cited as a fundamental barrier to the adoption of energy efficiency technologies. In this case, the remarkable aspect is the implementation of the capacity building strategy, which combined a theoretical and practical approach. Firstly, the UNSAM developed a group of theoretical classes to educate the local energy focal points. Then the focal points of each neighbour visited homes equipped with electricity consumption meters and surveyed their consumption. All this information was evaluated with the university, and specific case reports were prepared, which included personalized recommendations to reduce their consumption.

Figure 3 illustrates the successful elements identified from this experience, and its interrelation with the multi-stakeholder approach (shown by the green squares). As shown the virtuous circle starts with the bottom-up identification of needs (a project born from the people´s necessities), in which the role of the NGO is crucial. Then there is a capacity and information instruments built in conjunction between the NGO and the university, which includes training actions, audits and detailed reports on energy efficiency options for each home. These instruments are very important to remove the most important barriers in low-income homes and are (somehow) an enabling condition to promote energy efficiency throughout replacement of appliances. Finally, the role of energy utilities has been highly important to finance all these actions. This is a very important and novel aspect from this project.

Policy recommendations

The experience of technology transfer and adoption in developing regions shows that providing the technology (even for free), does not guarantee its adoption from a sustainable long-term perspective. The end-user uptake of technologies is fundamental, and requires a good knowledge of the technology and/or willingness to embrace new ways of producing or consuming energy, which in turn requires policy interventions. Based on observed experience in Latin America, the following are key questions that could be useful to guide the design and implementation of renewable and energy efficiency technologies transfer, particularly in low-income homes:

1. What are the country specific conditions in which the technology will be transferred?

2. What are the real energy needs, existing technologies and barriers to their uptake?

3. What are the existing institutions or local organizations that could increase the willingness to adopt the technology in the target group?

Regarding the first aspect, in the case of technology transfer, there are initial *conditions or enabling conditions* that need to be met or considered, for example:

- The existence of a national strategy and plan, including renewable sources and energy efficiency
- A careful evaluation of the most appropriate niche for renewable technologies, according to national circumstances and other factors
- Adequate institutional and legal frameworks that enable and incentivise renewable energy and energy efficiency actions
- Reliable data on electrification rates among the local population, including the share of the legal vs. illegal access in the most deprived urban and peri-urban areas
- The structure of electricity markets (how are decisions made including on prices, the role of private vs. public entities and their respective levels of accountability)
- The scope and content of laws and regulations regarding the role of foreign investors and actors in the energy market for both products and services at the household level
- It would be useful to create specific financial support funds, so that these types of initiatives could be replicated in other regions or countries

Related to the aspects that should be considered during the *design phase*, one of the clearest aspects arising is that technology transfer and adoption at the household level is more successful when it follows a bottom-up perspective instead a top-down one. The implementation of existing successful policies requires careful evaluation and adaptation to local circumstances. This means, on the one hand, that all the technologies need to be adequate in terms of scale, availability of resources, climate, local knowledge, culture, practices and customs. On the other hand, it is important to consider the difference between regions, also within one country there may be a broad diversity of social situations that determine the reaction to the technology to be adopted.

The end-user's perspective is key, regarding their problems and needs and their approach the solutions. This standpoint is contrary to a techno-deterministic view, which predominated among international organizations and national governments, which in the past have tended to predetermine the technologies to be transferred prior to any analysis of needs, problems and barriers. In contrast, during the design process, a multi-stakeholder perspective has proven to be a good practice. Including different views in the evaluation of the needs, problems, barriers and potential solutions is key, especially during the initial phases.

Focusing on the third dimension, the *implementation phase*, experience shows that the best way to remove some of the social barriers is to include local organizations or NGOs, which usually have strong knowledge of the problems and characteristics of local communities, including the capacities of households, attitudes and preferences. This aspect also relates to the importance of the multi-stakeholder approach, i.e. to include different views (especially local stakeholders), in the implementation of the policy, as much as possible. It is important to have key actors participating in the process in a committed way, both in the elaboration and implementation of the process.

As mentioned, the uptake of energy efficiency and renewable energy technologies faces various barriers. Therefore, they require a battery of instruments to promote their adoption, including financial instruments, economic incentives, capacity building, among others. It is advisable for communication and awareness actions to focus on the economic impact of the technologies, including long-term cost savings for households, rather than environmental benefits. It is very important to implement capacity building strategies in conjunction with the technology transfer policies. Long term sustainability of the technology depends upon local capabilities in the target community, regarding operation, installing and repairing the technology. It is also useful in some cases to develop demonstration projects at the community level, to increase the awareness among household consumers about specific technologies and their benefits.

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Technology transfer and implementation through investment in human capacity: a case study of the off-grid renewable energy sector in Africa

Abstract

Worldwide, governments set ambitious targets to mitigate climate change through their NDCs, and the policy and regulatory environment to accommodate the scale-up of mitigation initiatives is expanding rapidly. Human capacity will form an essential part of implementing the solutions to achieve those targets, especially for new or expanding technologies and markets. Yet, despite the importance of the software dimension of technology transfer and implementation at the local level, investment in skills and expertise development on-the-ground remains a largely overlooked form of technical and financial assistance. Consequently, significant skills and capacity-related gaps exist that limit progress in the rollout and scale-up of technology transfer and implementation in many non-OECD countries. In this article, I discuss these issues as they apply to the off-grid energy sector in Sub Saharan Africa (SSA), reflecting on the Off-grid Talent Initiative (OGTI) and the Transforming Energy Access Learning Partnership (TEA LP) project interventions aimed at strengthening local human capacities to help overcome one of the main structural constraints to clean technology uptake and expansion.

Climate change mitigation, energy access and the rise of the off-grid energy sector

Climate change is affecting every country on every continent, with 2011-2020 the warmest decade ever recorded.[i] Yet, we are still far from achieving our worldwide climate targets, including those for emissions reduction. Worse, emissions are expected to grow by 78% by 2050 compared to 2005 levels if no further action is taken. Energy accounts for 73.2% of global emissions, and demand has risen steadily for the past half century, with fossil fuels providing almost 80% of world energy supply.[ii] A transition from fossil-fuel driven energy systems towards zero-and low-carbon energy systems is thus urgently needed to lower energy-related emissions.[iii] The Covid-19 pandemic and resulting economic crisis have defined energy and emissions trends in 2020 and resulted in a drop in primary energy demand by nearly 4% in 2020, and a drop in CO2 emissions of 5,8%.[iv] What is important about this trend is that whereas the crisis drove down fossil fuel consumption (largely driven by a decline in transport), renewable energy was largely immune to this external shock, and solar PV and wind energy reached their highest ever annual share of the global energy mix, increasing by more than a percentage point to over 20%.[iv]

Equally important to lowering emissions is our commitment to ensure universal access to energy, as this increases well-being and enables advancements in economic development, especially in low-income countries. We must, therefore, ensure that addressing climate change goes hand in hand with achieving the sustainable development goals (SDGs). SDG 7 strives for universal energy access for the 759 million people worldwide who still lacked access to electricity in 2019,[v] and who are nearly all located in Sub Saharan Africa and Asia. Crucially, this must be achieved while minimizing GHG emissions, and using a range of technologies to provide basic and affordable energy services. Renewable energy technologies are set to play an important role in reaching energy access targets, and have the dual benefit of increasing access to energy without increasing emissions. To achieve this, governments, the global energy industry and society as a whole must collaborate on an unprecedented scale.

Off-grid technologies, including stand-alone energy systems and mini-grids, operate detached from the traditional centralised grid approach, and use local, renewable sources of energy, including solar, water and wind. They have demonstrated the crucial role renewable energy technologies will play in reducing emissions whilst increasing access to energy.[vi] Because of this, it is expected that by 2030 over 60% of new access to electricity will be powered by renewable energy sources, of which around half is provided by off-grid and mini-grid systems.[vii] This is made possible by a combination of innovations in technological 'hardware' and its transfer, accompanying 'orgware'-related factors such as enabling policies, embeddedness of the off-grid sector in organisational approaches and strategies, as well as dramatic reductions in the price of solar photovoltaics (PV) and wind turbines. The latter have made off-grid energy systems increasingly a cost-effective solution to address both SDG 7 and GHG reductions.

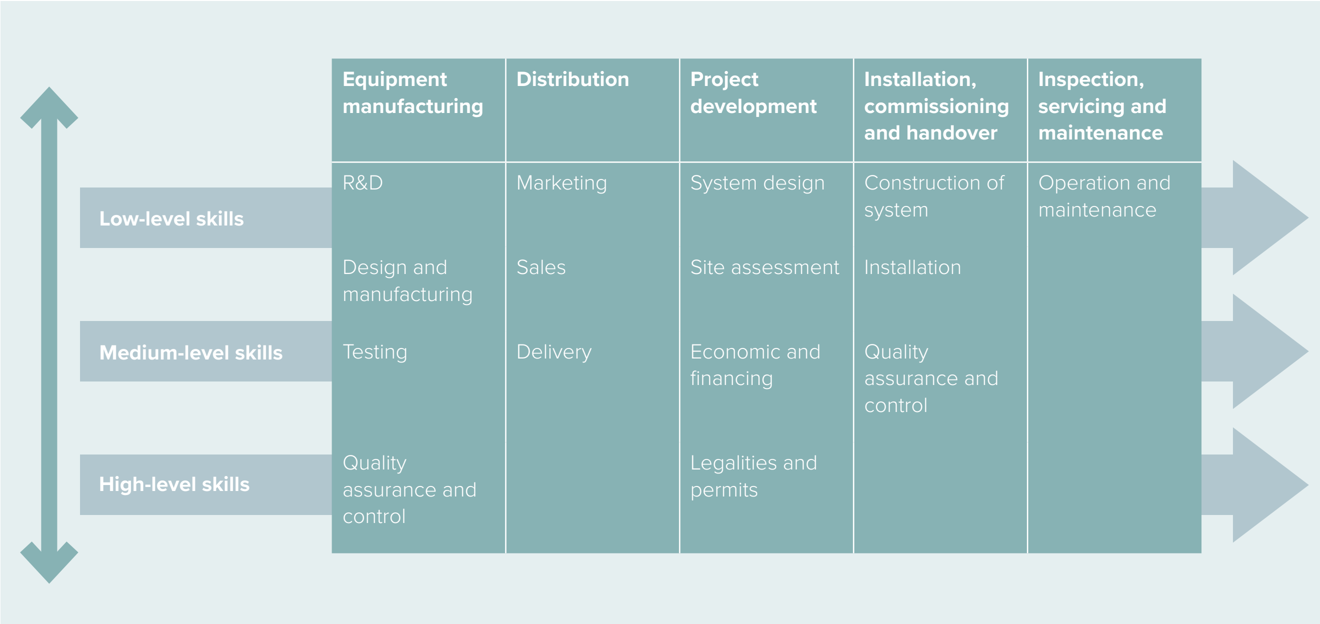
The off-grid energy sector represents not just opportunities to contribute to climate change mitigation and energy access it also represents a new market for businesses. To illustrate this, the off-grid solar sector has attracted over $1.5 billion in investment since 2012 through a combination of public and private-sector finance, and reached an $1.75 billion annual market which in the past decade served over 420 million users and continues to grow.[viii] The increase in investment has been further accompanied by technology innovation and transfer, innovations in business models for the off-grid sector, and enabled by national and international financial support as well as changes in policies and regulatory spheres to create an enabling environment for the off-grid energy sector.

However, a key dimension that remains overlooked in technology transfer and development of local supply chains is the 'software' dimension, in particular the knowledge associated with the production, use and implementation of the hardware, and which includes the skills and expertise dimension. The lack of human capital in the off-grid energy sector, in the form of an appropriately skilled workforce, is hindering scale-up of the sector in the areas with least access to energy.

Skills development to increase the human capacity needed to scale-up the off-grid sector

Human capacity, in the form of a well-trained workforce, will form an essential part of implementing off-grid energy solutions. A skilled workforce, both on the ground and internationally is essential to roll-out and scale-up energy projects.[ix, x] Despite the crucial importance of human capacity, investment in skills and expertise development on-the-ground lags behind other forms of support for technology

Figure 1. **Example of skills required in the energy supply chain**



innovation and transfer. Moreover, it remains among the least common form of technical and financial assistance considered nationally and internationally.[xi] This is surprising, because the skills gap directly hinders achievement of climate change and energy access goals and holds countries back in being able to capitalise on the benefits the increase in available funding in the off-grid sector can bring. Thus, the cross-cutting role of human capacity becomes crucial as both a catalyst and booster for sustainable development. Without a properly skilled workforce it will be impossible to achieve transformative change in energy access, in particular one 'that is effective, equitable, empowering and long-lasting' *and* will help address emissions reduction targets.[xii]

The Skills Gap in the Off-Grid Energy Sector

The skills gap is large and encompasses skills throughout the supply chain. For example, skills shortages are a major barrier to the advancement of climate change adaptation and mitigation strategies but also forms an important opportunity to advance productive employment.[xiii] We find that this skills gap is the same in the off-grid energy sector. Because of the inability of companies to find local staff with appropriate skillsets, many off-grid energy projects remain reliant on the 'import' of higher-level skills as companies struggle to find staff with the required skillsets.[xiv] Having a skilled local workforce would not only likely increase the quality and sustainability of projects because of its embeddedness in the local context, it also would lower the costs of energy projects.[xv] During the scoping study of the TEA programme, we found that insufficient human capacity has resulted in a situation in which many jobs are 'flown' in. This not only reduces the development benefits and the much needed jobs in many countries, but would also hamper progress towards mitigation and energy access targets.

Underlying the skills gap is both a lack of training options and trained personnel.[x] Despite the identified skills-related challenges for the energy sector, the increased attention it is receiving from donors and governments, this remains a constraint to our efforts to scale up the off-grid energy market. Skills gaps exist at many levels, vocational and Higher Education (HE) levels, encompass all areas of the value chain, e.g. sales and marketing, technical, managerial and business-related skills (See Figure 1), and encompass different levels of skills. To illustrate, the technical skills required related to R&D would predominantly operate at a highly skilled level, whereas operation and maintenance would require low-medium level skilled professionals.

From this starting point, I zoom in specifically on HE skills and expertise development as a critical element in technology transfer and implementation for the off-grid energy sector, and to prepare the future workforce across the energy access value chain. Skills development at HE level holds significant potential to enable a locally-driven scale-up of off-grid energy initiatives which can contribute to the long-term transformation of energy systems in SSA.[16] I will explore this using two examples, namely the Off-grid Talent Initiative (OGTI) and the Transforming Energy Access Learning Partnership (TEA LP), developed for the FCDO-funded programme 'Transforming Energy Access'. These programmes, which we implemented in partnership with the Carbon Trust, Shortlist, AMI and the University of Cape Town, show how targeted and tailored programmes can make an important difference, and identifies key areas of attention for skills development at HE level in the off-grid sector, which are likely to be transferrable to other climate change sectors.

Exploring the skills gap in the off-grid energy sector

The off-grid sector: jobs, skills and sustainable development

Many organisations, including IRENA, SEforAll and Power for All have linked the off-grid energy sector to job creation and economic growth.[17] [xvi] Globally, the rapidly increasing work force in the off-grid energy sector accounts for 10.3 million jobs. However, in Africa, employment remains limited, with only 76,000 jobs in the renewable energy sector on the whole continent. [xvii] The competitive wages offered by the international off-grid sector would directly benefit employees and their families, but also increase government revenue via taxation and social security benefits, all contributing long-term to the wider economy.[18] The off-grid energy sector can thus be an important driver of sustainable development locally. However, in many areas of skills development, large gaps are identified as to-date limited training offered by educational organisations locally because the sector is still in relevant infancy. [xviii] Furthermore, sluggish changes in enabling environments for the off-grid sector such as policy/regulatory aspects and government-led efforts at building human capacity for the off-grid energy sector are minimal,[xix] which we found were exacerbated by the bureaucratic systems of HE. As such, training providers are often slow to respond to this opportunity as the design and implementation of training programmes is generally a lengthy process. This has left the private sector to do most of the heavy lifting to date. For the TEA programme to have an impact on sector scale-up, we felt we had to help speed up this process in particular at the HE level.

Identifying the skills gaps in the off-grid sector at HE level

What constitutes skills for the energy sector at HE level? Skills are the ability to do something well. There is an essential difference between skills and knowledge, which refers to the way we understand and remember information. Skills instead refers to the way knowledge is selected, used and applied in different circumstances, for example when facing diverse or unpredictable challenges.[xx] This difference is crucial for understanding the skills gap in the off-grid sector, where individuals may know the mechanics of an off-grid energy system, and potentially the steps in designing a local system, but may lack the know-how to implement an energy project, deploy them in different contexts, or handle the challenges involved in their implementation. Furthermore, skills can be divided into 'hard skills', which consist of specific technical and content knowledge and 'soft skills', which are transferable skills that enable people to successfully apply their hard skills in a workplace (Table 1).

This is backed by the academic and grey literature on the topic, which indicates that a general skills shortage and lack of capacity building programmes contributes to the delay of many projects in SSA and the local development benefits they bring. [xvii, xvi, xxi, xxii, xxiii] Key skills gaps in the off-grid

Table 1. Definition of hard and soft skills and examples of their application in the off-grid energy sector

	Hard skills	Soft skills
Definition	Specific technical and content knowledge and training	Transferable skills that are not content-specific but consist of attributes that enable people to interact with others and function successfully in the workplace.
Examples of HE-level skills in the off-grid energy sector	Energy modelling skills, technical engineering knowledge, software development, legal expertise, human resource professionals	Leadership, problem solving, group work, communication skills, stakeholder or customer management skills

sector relate to installation and design, project management competencies, as well as sales and marketing. Because these are currently lacking, off-grid energy companies have started to develop their own training courses to address skills gaps among their employees and after recruitment. For example, the 'Academy' and 'University' programmes designed by BBOX and MKopa are in-house training programmes to upskill staff as well as the training programmes developed by Schneider electric.

A skilled workforce is needed throughout the entire energy supply chain – from energy production to end-users. If energy projects are designed with the implementation context in mind, development of local expertise becomes integral to the project, and this is needed to replicate and scale-up successful initiatives, support ownership of stakeholders, and crucially, foster sustainability beyond the withdrawal of external partners.[xii] The off-grid sector requires a skilled workforce in a range of areas, but can be broadly divided into two categories, covering vocational skills and higher-level skills.

Training institutions have grown too, in part to meet the needs of the off-grid sector in many countries. However, the reality of vocational training is that institutions remain very technically focused, despite a growing need of the sector for employees that have a range of skills, including sales and marketing, entrepreneurial, data and basic IT, alongside technical skills.[xi] This issue is even more prominent in the area of higher-level skills. Where larger companies (including transnational companies) benefit from business development support, technical assistance or specialist services, this is often not available for smaller enterprises. This is despite the need for support across a diverse range of business functions including managerial competences, finance, sales and logistics, business development, as well as technical assistance.[xxiv]

In 2008 a survey conducted on skills needs in the energy industry found that 70% of energy companies felt they would not have sufficient leadership talent to meet the industry's future challenges, and that internal training and development programmes are delivering insufficient numbers of trained personnel to develop into senior roles.[xxv] Similarly, energy sector stakeholders felt that the skills shortage would expect to result in 'poaching' of employees. The report further recommended to 'Develop new and potential graduates at an early stage to combat lack of experienced hires for key roles in an expanding industry – employers need to be more innovative in their methods of training and development, looking for efficient and effective ways of benchmarking employees' competence and giving them the experience and support to develop those skills' (p.3).

The Off Grid Talent Initiative (OGTI): TEA's response to overcoming short-medium term skills shortages in the energy sector

In the OGTI programme we set out to facilitate and promote careers in the off-grid energy sector. Responding to key market needs expressed by off-grid energy enterprises, OGTI supports talent at junior and mid-management levels in off-grid companies.[xxvi] Since 2019, OGTI has implemented a graduate work placement programme and a mid-management development programme. Both programmes have made significant impacts building human capacity for the transfer of off-grid energy technologies in the SSA market, as I will further illustrate below.

Empowering Managers

Through the 'Empowering Managers' programme we target mid-level managers in off-grid companies and provided training that equips team leaders and supervisors with the soft skills that will help them to lead dispersed teams, manage rapid growth, create a performance culture, and help front line staff to become more productive. All these were competencies identified by stakeholders as essential to scale-up the sector.[xxvi] Implemented on-the-ground by our partner the African Management Institute (AMI), OGTI combines online and mobile tools with experiential in-person workshops and on-the-job practice and support. To ensure buy-in from the sector, we request companies to provide a financial contribution for their staff to partake in the programme.

Since its inception in October 2019 the programme has enrolled over 476 managers across SSA. The programme has reported important impacts in both human capacity development *and* improved operation at a company level. To illustrate, we found that 75% of off-grid companies whose staff benefited from the mid-management training programme report improved personnel performance that contributes to company success, hereby building important capacity for the sector. Examples include improved employee competencies and performance, but also the multiplier effects of having a good manager, which reduces employee turnover, and more motivated and productive teams. Furthermore, good management practices and habits are institutionalized within the company for future managers, thus strengthening the management capacity. This not only helps improve management of companies overall, but also helps build the sector as a whole.

At the time of writing this piece, we found that 100% of off-grid companies whose staff participated in the Empowering Managers program reported that upward mobility and/or pay rise for those staff is likely, and to date 23% of graduated participants have reported a salary increase or promotion in their job roles as a result of the programme. Such upward mobility may also reduce the turnover rate and help retain skilled individuals in the sector. Furthermore, we found that in a post-placement evaluation survey 50% of companies with staff who participated in the Empowering Managers programme reported a reduction in staff turnover rates. The OGTI has not only demonstrated its effectiveness but has also proven to be in high demand and impact: over-subscription of the programme has demonstrated the demand for a results-oriented training programme for which companies are willing to pay.

Graduate work placements

Through the Clean Energy Leaders programme, we set out to address the 'education-employment gap' for recent graduates. The Clean Energy Leaders programme matches the skills of young graduates with the sector demand and place graduates in companies to gain experience and competencies required by the sector. Implemented by Shortlist, the programme provides young professionals (who have little or no previous work experience) with a structured learning experience in organisations working in the sector. Through co-funded placements, we set out to reduce the risks for companies to hire and scale their entry-level recruitment. In the programme, young graduates are offered stable work placement opportunities with sufficient time to grow in soft and technical skills through on-the-job training. The first placements started in November 2019, and by December 2021 over 350 candidates (of which to date 56% are women) will have been placed in companies in 10 countries in SSA, including in roles such as accountancy, business development, research analysts, logistics, digital tech and engineering. We found that to date 12% of placements left their roles before the completion of their term, which was primarily due them being offered other opportunities. The programme's impacts are significant and we found that, so far, 94% of OGTI Clean Energy Leaders were absorbed into full time jobs with their companies after the placement period of 6 or 12 months. Furthermore, the programme achieved an approximate 60/40 private sector leverage split on the graduate placement salaries, demonstrating that companies see the value and invest in the placement model.

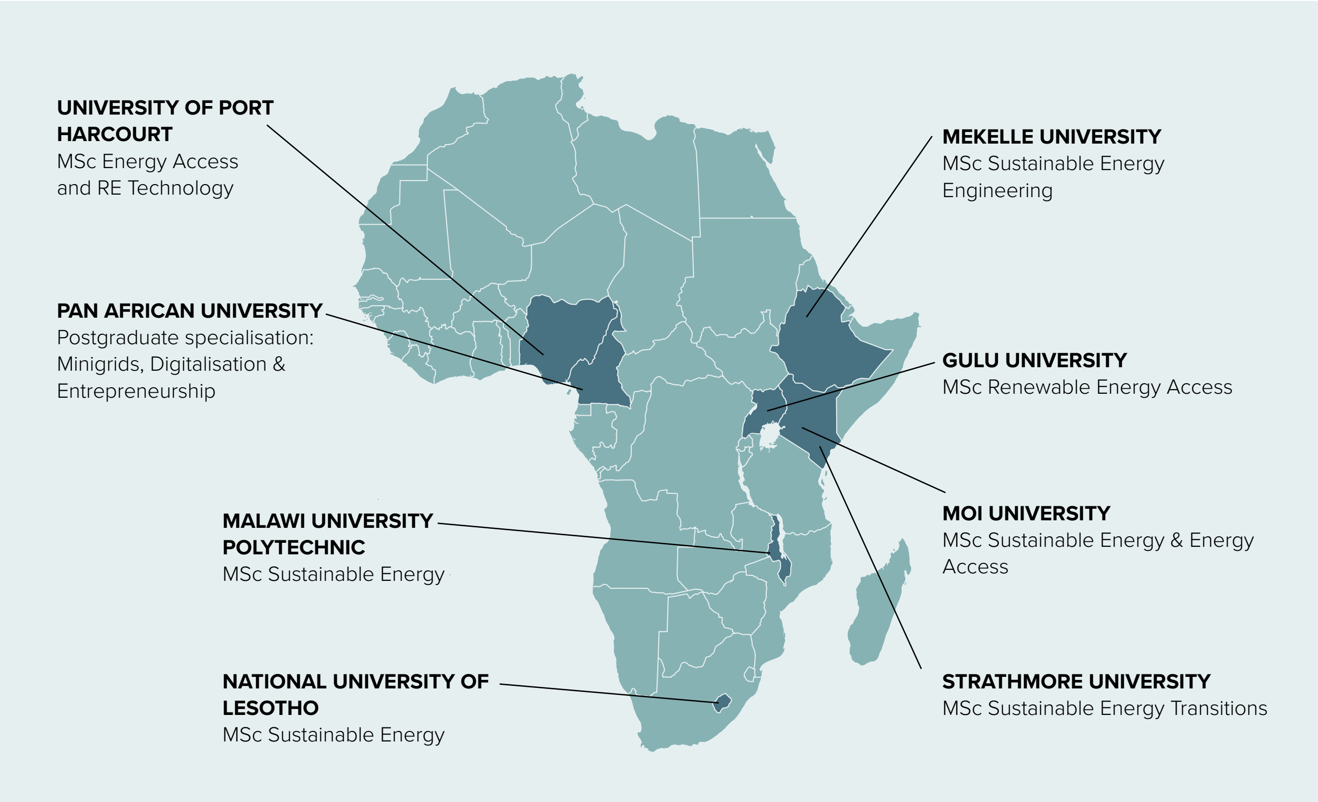
The Transforming Energy Access Learning Partnership – TEA's a long-term approach to bridging education and competencies required by the energy sector

We established the TEA Learning Partnership (TEA LP) to build the necessary human capital to achieve universal access to energy. The TEA LP provides technical and financial support to eight universities across Africa to develop new postgraduate curricula for the energy access sector (Figure 2). To ensure the content is tailored to the national context, each university develops the curriculum based on their strengths and informed by their market engagement with regional energy access sector stakeholders. Technical and educational support is provided by a dedicated team of experts, who, together with the partners upskill both the staff at the university and the curricula to the changing skills needs of the energy sector. The partnership commenced in 2019 and the first programmes and courses launched in early 2021. In addition, we provide student support to attend the programmes through the TEA LP scholarship programme, which we implement in partnership with the Lichtenstein Institute for Strategic Development.

We applied five core principles when designing the curricula:

- Each university conducted a market needs assessment and ongoing engagement with the energy sector, which they use in the design of their outcomes-driven curriculum to ensure it is **responsive to sectoral needs**;
- To produce well rounded graduates with diverse skillsets and competencies, we supported universities to transcend the single disciplinary approach to encompass other energy access-relevant disciplines, resulting in a **multidisciplinary curriculum**.
- We applied **gender mainstreaming** to ensure the programmes contribute to addressing gender inequality in both course content and classroom and teaching settings. We achieved this through the application of the 'six lever framework',[xxvii] which we developed specifically for this purpose.

Figure 2. Member universities of the TEA Learning Partnership



- We strongly emphasizes the development of **soft skills** together with discipline/subject specific knowledge and competencies required in the workplace.
- Our partners developed a comprehensive business plan and marketing strategy to ensure **operational success and longevity**.[xxviii]

Through the above activities we supported the development of eight new curricula which are 'first-of-their-kind' in Africa, and the first curricula to respond directly to SDG 7, all of which will have launched by January 2022. The capacity building focused on university staff and the co-designed, innovative templates to support the curricula are changing the way in which energy access education will be taught. As one of the partners commented: the templates *'provide clarity for the lecturer, a clear map of lesson plans',* in doing so not just building the capacity of the universities and lecturers involved, but also contributing to maintaining the 'institutional memory' related to the design and implementation of the programme. Alongside this, we support the faculties of TEA LP members with business plans and marketing, to ensure the long-term financial viability of the programmes.

Since the beginning of the partnership we found that a key strength of the programme was its emphasis on the collaborative partnership, where partners across Africa draw on and share their own local and contextualised experience and expertise. Whereas initially, this was feared by some lecturers as *'extra work and stress for staff and students alike',* feedback and evaluation showed a significant shift in favour of embracing the integration of soft-skills, interdisciplinarity and a collaborative approach with the energy sector. One of our partners at Gulu university, for example, commented that *'this appointment ...allows you to be an ambassador of the unique curriculum development process to members of Gulu University and other universities in Uganda'.* This demonstrates the transferability of the process to other universities and even to spread across the continent. The impact of our programme, although still early on, has sparked interest even beyond the energy access sphere. For example, the Council of Higher Education in one of the partner countries has expressed an interest in the novel curriculum templates and highlighted its transferability to other HE contexts.

Transforming skills development at higher education level: towards a structure for skills development in the off-grid sector

Emerging from our extensive engagement with the off-grid energy sector and incorporating lessons learned from the OGTI and TEA LP programmes is a structure that supports investment in human capacity in the off-grid energy sector.

Engagement and collaboration

13 years after the 'skills needs in the energy industry' report was launched, the key conclusions and recommendations remain relevant, including the need for close engagement with industry to delivering a skilled workforce that meets business needs.[xxv] Moreover, it has become even more pressing for technology transfer and innovation in the off-grid energy sector. At present, the internal training and development programmes designed and implemented by off-grid energy companies are unable to deliver the numbers of trained personnel required to fulfil the existing skills needed for senior roles. Engagement and collaboration with training providers across Africa can, in the long-term, reduce the need for companies to design their own training programmes.[xviii, xvi, xix]

The off-grid energy stakeholders that we engaged during in the TEA programme stressed the ongoing importance of training programmes to engage extensively with the sector. This not only ensures that training can become more responsive to the needs of the sector, but also ensures that new entrants into the sector can hit the ground running, hereby reducing lag times in their optimal function within off-grid companies. It is thus important that skills and expertise development at a higher education level take an integrative approach, at multiple levels.

For example, in both the TEA LP and OGTI initiatives, there has been extensive and continuous engagement with the energy sector across a range of levels, including in the design and implementation of curricula and training programmes to ensure it meets the needs of the sector, creating a pipeline of graduates that can easily stream into the off-grid sector. This involves sharing information and training materials, and to provide a feedback loop to ensure that innovations and trends in the sector become part of an adaptive training programme. This allows for a better integration and alignment of skills providers with the needs of the sector.

Integrative approach to skills development -soft and hard skill development

The integration of different competencies and disciplines is essential to scale-up the number of skilled professionals available for the off-grid sector. Stakeholders in the off-grid sector consistently reported a mismatch between the skill sets that universities are developing and what the sector needs. Issues raised include the absence of 'talented generalists', instead of just highly specialised young candidates, e.g. with an electrical engineering degree. This was confirmed by the findings of the TEA scoping study, which identified that the way in which institutions of higher education in SSA provide training is often poorly aligned with the needs of the dynamic off-grid sector.[xxvi] This mismatch of skills is not surprising given the relatively new status of the off-grid electricity sector on any substantial scale. Important for transforming the skills development sector at HE level is that students need to be competent in content knowledge of an energy technology or energy-related topic. However, graduates also need to understand the off-grid sector in which they would be employed, as well as having the transferable skills required to function in the work place.[xxviii]

Industry stakeholders have repeatedly emphasised the importance of so-called soft skills, such as critical thinking, communications, teamwork, and problem solving, and indicated that this is what they would search for in graduates.[xvi xxvi] The literature confirms that projects which involve staff with soft skills are much more successful.[xxi, xxii, xxiii] Yet, institutions of higher education, among the main providers of skilled graduates to the sector, lag behind in integrating this in their modes of learning and teaching, something that is caused by the knowledge-focused nature of many postgraduate programmes in SSA. In these programmes, there is too often a pure focus on content knowledge, at the cost of employability and usability of knowledge gained in the work place. To illustrate this, Fisher and Scott[xxix] highlighted the problems associated with the 'low participation, high attrition' system, which at the time was prevalent in South African Universities. Thus, alongside the 'hard' content knowledge, there is a demonstrated need for furthering 'soft skills' of graduates,[xxx] for example in the area of smart-grid development,[xxxi] but also more broadly.[xxxii]

Soft skills are developed more through the manner in which courses are conducted, rather than through specific content in courses. These soft skills are crucial to the functioning of a graduate in the off-grid sector, and therefore to the successful implementation of energy projects. Thus, in addition to topical knowledge on their area of expertise, graduates need to be equipped with a range of softer skills such as critical thinking skills, problem solving attitudes, good communication and team working abilities. This will enable graduates to apply their content knowledge in real-world situations such as the off-grid sector. Soft skills are an area of skills that receives much less attention in training activities, and the 'soft skill' approach, although demonstrated by the literature, to date is not common practice in many universities in SSA. The TEA LP changes this dynamic and trains university staff to design and deliver programmes that respond to sector needs, whilst the OGTI programme addresses the short-term need for graduates that require soft skills. To achieve this, there is a strong need for close engagement with the off-grid energy sector to deliver both relevant and high-quality qualifications by training providers, *and* ensure that these programmes respond to sector needs. Naturally, this requires close interaction (and/or partnerships) between training providers and the sector.

Balancing short-term skills gaps and long-term skills needs

We found that there is a critical temporal dimension to the development of skills and expertise. For example, as the off-grid energy sector is currently experiencing critical skills gaps, and off-grid solar companies have made considerable efforts to build up their own workforces through in-house training and support for employee's personal development.[xviii] Although this is a promising start, the demand for skilled graduates far outweighs the available training. Furthermore, the purpose of those programmes is to train companies' own staff, and not to service the broader sector. Short-term training initiatives are required to fill those gaps, a gap that the OGTI programme aims to fill. For example, GOGLA, in their 2019 report *energizing job creation: employment opportunities along the off-grid solar value chain*, highlighted that the off-grid sector uses a combination of on-the-job training to adapt existing skill sets to their needs, specifically jobs related to management, sales and logistics; in-house training programmes for logistics and sales staff; and source external training for their management and technical staff.[xviii] Stakeholders from the sector indicate because this is the result of a lack of a pipeline of suitably skilled graduates.[xxvi] As African Development bank President Dr Akinwumi Adesina indicates *'we are essentially training our youth for jobs of yesterday, not the jobs of the future (p.4)'.*[xxxiii]

Initiatives such as OGTI's graduate placement programme are essential as it addresses the 'education-employment gap' to get young graduates that may have strong skills in their respective disciplines that lack the professional skills and competencies required by companies, and are therefore not 'workplace ready'. It attracts recent graduates to the sector and upskills them to fit the needs of the off-grid sector whilst creating a learning environment that enables them to grow into their roles. Similarly, to ensure the current workforce has opportunities for growth in the sector, training focused on mid-management has an important role to help people climb the off-grid energy career ladder. Companies pointed to the mid-management competency gap, and indicated that they often have to fill positions at this level with fairly inexperienced employees who lack experience and key competencies such as managing others and themselves, communication, team-working, planning and problem solving, as well as having a general entrepreneurial and problem-solving mind-set.

However, despite their vital role in ensuring the off-grid sector operates and scales up at present, these are not sustainable ways to provide a skilled workforce in the long-term, and institutionalise energy access training programmes. For countries in SSA to become an integral part of the off-grid energy sector and to capitalise on the many opportunities available to grow the sector, a long-term pipeline of skilled individuals is required at the graduate level. This starts with training of graduates at higher education organisations, and the institutionalisation of programmes that develop appropriate skill sets. As the development of curriculum and training takes time (and students need time to study the programmes), programmes developed now will only deliver impact in 5-10 years.

In the long term, these graduates can provide the shift needed in a skilled workforce that is effective for the off-grid energy sector and can help drive technology transfer at the local level. It also enables countries to capitalise more from the socio-economic benefits associated with employment and participation in the sector. For countries to become an integral part of the off-grid energy sector, we found that such a long-term focus is essential. Unfortunately, because of the long-term focus of these initiatives, this area of skills building has received little attention from donors and the private sector alike. Nevertheless, it is a critical building block for creating a pipeline of skilled graduates for the off-grid sector in SSA. As higher education generally sits in the realm of government, an approach that includes government stakeholders, the private sector and where possible donor funding would help to address this critical skills gap.

Africa-centric

To ensure a sustainable and thriving off-grid energy sector in SSA, it is essential that an Africa-centric approach is taken to achieve this. At present, the sector remains largely dominated by companies and even staff from other geographic regions. Although strong international engagement is not a problem *per se*, a skilled workforce at the local level could increase the long-term sustainability of the sector locally, increase value-for-money, and allow for much needed local development benefits. As raised earlier in this article, positions offered by the off-grid solar sector are likely to have substantially higher wages than the average wages of countries in SSA.[xviii] For individuals in SSA to benefit from this, those jobs need to become available on the continent, rather than be filled by others due to a lack of suitability skilled staff.[xxxiv] An Africa-centred approach to skills development can reduce the need to import skills. To capitalise on the opportunity for job creation, support for relevant skills training is essential, but this is only likely to happen if the off-grid sector becomes fully embraced by government, higher education and private sector stakeholders alike in target countries. The TEA LP is one of the few initiatives that provides an Africa-centric (and African-led) focus to skills development, and by providing technical assistance, financial and networking support. Our initiative thus aims to strengthen skills development by African institutions for Africans, to reduce the long-term need for international involvement and provide training in-country by local experts.

Inclusive

In addition to the key areas to consider in skills development discussed above, it is essential to ensure that skills building is happening in a way that is equitable and inclusive. This seems a no-brainer, but despite the rhetoric surrounding inclusivity in skills development and in the workplace, in particular in energy professions, gender and social inclusion (such as youth, people with disabilities and other disadvantaged or under-resourced groups) still require a lot of work. To illustrate this, although the off-grid sector performs better on gender representation and inclusion than the traditional energy sector, women remain underrepresented in the off-grid sector in particular at managerial and technical levels.[xvii] This is problematic, because achieving gender and social inclusion is not only an important goal in itself, it also leads to better outcomes as the perspectives of a range of customers, end-users, decision-makers etc are represented.

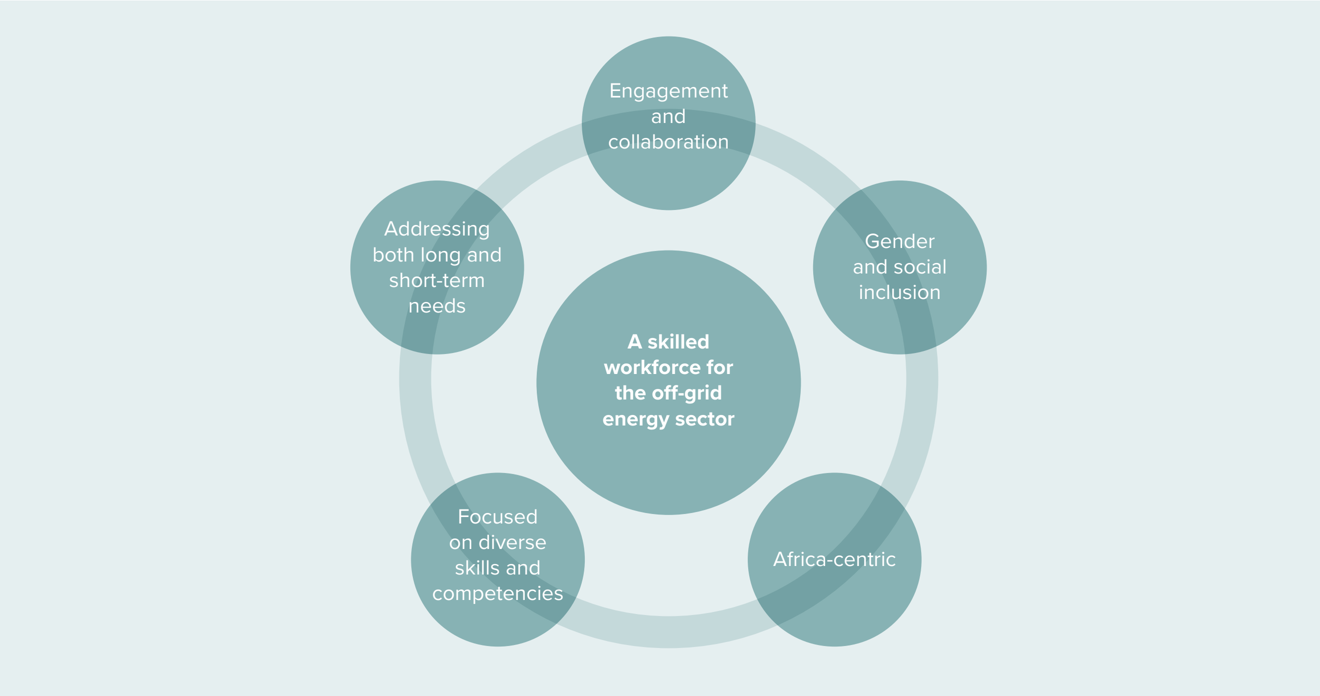
IRENA highlighted that a variety of actions are needed to increase diversity, including workplace flexibility, mentorship and training, parenting support, transparency and fairness in process, equal pay and diversity targets.[xvii] The OGTI initiative has focused on addressing the inclusivity issue at multiple levels, for example by focusing on youth, but also by using special marketing techniques that attract women to the training programme and the 'speak up to lead' programme, which aims to help women in the workplace to lead effectively. Similarly, the TEA LP, in addition to its core focus on youth, has a dedicated a team to assist universities with gender mainstreaming of their curriculum at both content and process levels, and which aims to increase diversity and inclusivity at higher education level.

Accelerating technology transfer and implementation in the off-grid sector: conclusions on the way forward for investment in human capacity and skills development

To achieve the ambitious climate change mitigation targets set by country governments whilst achieving universal access to electricity, investment in human capacity, in the form of a well-trained workforce, will increase the quality and effectiveness of the transfer of off-grid energy technologies and their implementation at the local level. At present, the off-grid renewable sector is severely hindered by a lack of an appropriately skilled workforce and in this article I have argued that as a still nascent sector, training providers have not always yet fully responded to skills needs of the sector. As this severely hampers the technology transfer and implementation challenges for energy technologies, I proposed areas that will help structure the development of human capacity at a graduate level (Figure 3).

A skilled workforce is needed throughout the entire energy supply chain – from energy production to end-users. As a consequence, training and skills development activities become an essential component of successful projects aiming at enhancing energy access and more broadly the successful scale up of the off-grid energy sector. The structure presented above, if jointly implemented by training providers and the off-grid energy sector, enhances alignment between the skillsets required by the sector. Further, it can be used to set up new initiatives as well as strengthen existing skills

Figure 3. Key areas of focus for improved training for the off-grid sector



initiatives, which link energy, climate, and hence sustainable development, stressing the importance of renewable energy and energy efficiency to achieve growth and to limit climate change.

The experiences of these initiatives and similarities between technology contexts suggests that these insights will also hold true in other technology transfer contexts, or at different levels of skills development, for example at vocational training levels, where engineers, technicians, and more end-user focused professionals such as designers and sales people collaborate from their own professional background. Another example includes the transferability of these findings to other climate change sectors, for example the agricultural sector, where technology transfer for climate appropriate agriculture is likely to suffer from similar skills-related challenges, e.g. in relation to hard and soft skills, workplace readiness and diversity.

Crucially, in addition to efforts from the private sector and training providers, it is essential that government stakeholders are on board to institutionalise training programmes that ensure graduates are workplace ready. For example, with support from governments and other stakeholders, responsive and comprehensive training programmes can be promoted to ensure that human capacity development is compatible with the scale of needs in the off-grid energy sector, aligning energy access investments with climate change mitigation efforts that have a strong local drive. Human capacity building and skills development should go hand in hand with other efforts to scale-up adaptation and mitigation responses, to minimise the risk of future skills-related bottlenecks that stand to delay our global responses to the dual challenges of climate change and sustainable development.

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Untangling blended finance for investments in climate technologies: pathways to implementation in support of the Paris Agreement

Abstract

According to the International Energy Agency (IEA, 2021[i]), emerging and developing economies currently account for two-thirds of the world's population, but only one-fifth of global investment in clean energy, and one-tenth of global financial wealth. Further, annual investments across all parts of the energy sector in emerging and developing markets have fallen [in 2021] by around 20 percent since 2016, and they face debt and equity costs that are up to seven times higher than in the United States or Europe. The climate finance literature is rich with the concept that patient, concessional funding from government or multilateral sources is key to de-risking projects and, subsequently, crowding in private capital. The intention of this paper is to untangle blended finance and its implications at the transactional level, as a means to scale up investments in climate technologies aligned with the ambitions of the NDCs to the Paris Agreement.

Investment in climate technologies

Climate technologies include wind and solar, electric mobility/transport, renewable resources (biofuels) and storage assets like batteries. These are considered core constituents for achieving 'net zero' carbon emissions by 2050. The total global investment opportunity is estimated at US$ 50 trillion, carrying the potential of US$ 3-10 trillion of earnings.[ii]

The mobilization of climate finance in emerging and frontier markets is a fundamental condition of reversing the pathway defined by the IPCC in August 2021. Globally, trillions of dollars are required for countries to meet their clean energy and climate goals.[iii]

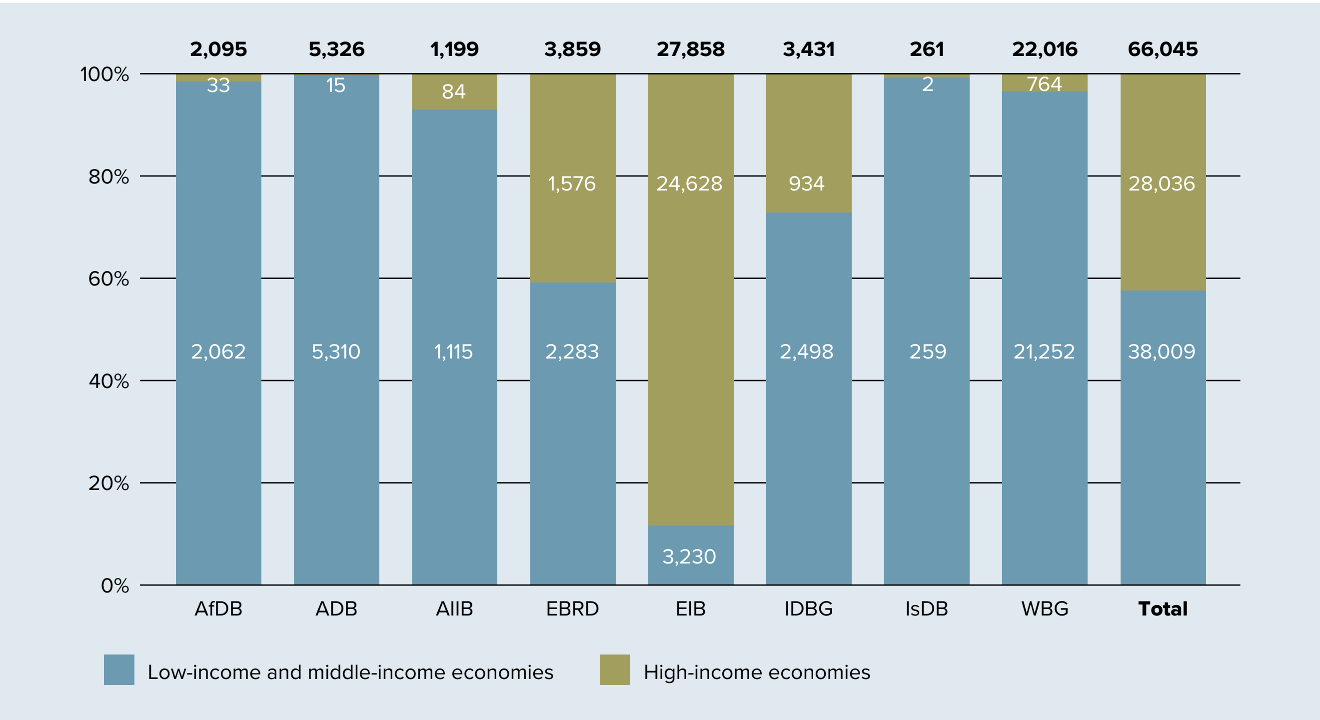
The balance of climate investment needs to continue to come from private sources. "While the bulk of investment will need to come from the private sector, public capital providers (such as multilateral and national development institutions) have an important role to play in terms of mobilizing private sources."[iv] And public investment entities, such as multilateral and international development finance institutions, are positioned to play an essential role in terms of catalyzing this capital.

For private investors, committing capital to a climate-related project involves capturing, downloading and analyzing a lot of information—it is not a landscape where emerging, innovative business models and technologies capture the attention of risk-flexible venture capital.[v] Rather it is a valley of data and due diligence. Private capital analyses rates of return, costs of capital, timelines, probabilities of default and a range of risks; all against varying scenarios.

Those firms also consider the impact, reach and scalability of climate-responsive enterprises. However, these factors are not weighted at the expense of the economics of a project. Rather, a decision on investing integrates a range of factors including—but not limited to—the factors noted above. These assessments can be extremely rigorous, depending on the size and ambition of a project and the prospective scale of commitment of the investor.

There is a growing universe of tools and practices that can be used to facilitate and encourage investment in renewable energy solutions. These include (1) transparent agreements in power generation and offtake; (2) fuel switching incentives and carbon markets; (3) favorable investment policies

Figure 1. Total MDB climate finance commitments for all economies, 2020 (in US$ million)[viii]



such as tax incentives; (4) financing instruments such as green bonds; and (5) risk assumption, particularly at the front end of projects and interventions.[vi]

For the fifth point (noted above), development finance institutions, such as the African Development Bank, Asian Development Bank and the World Bank, play a pivotal role. These institutions employ a variety of instruments and models aimed at taking on the upfront risk of clean energy and climate-related projects in order to assuage private investors directly or create conditions that make international investment viable.

Development finance institutions

Multilateral development banks and other development finance institutions have been integral in the pursuit of Sustainable Development Goals (SDGs) 7 (affordable and clean energy) and 13 (climate action). They serve as a source of investment in low-carbon activities, targeting and tracking their climate finance investment scenarios. For instance, AfDB set a target of doubling climate finance to US$ 25 billion for the period 2020-2025.[vii] The Asian Development Bank has targeted US$ 80 billion for climate investment from own resources for the period 2019-2030.

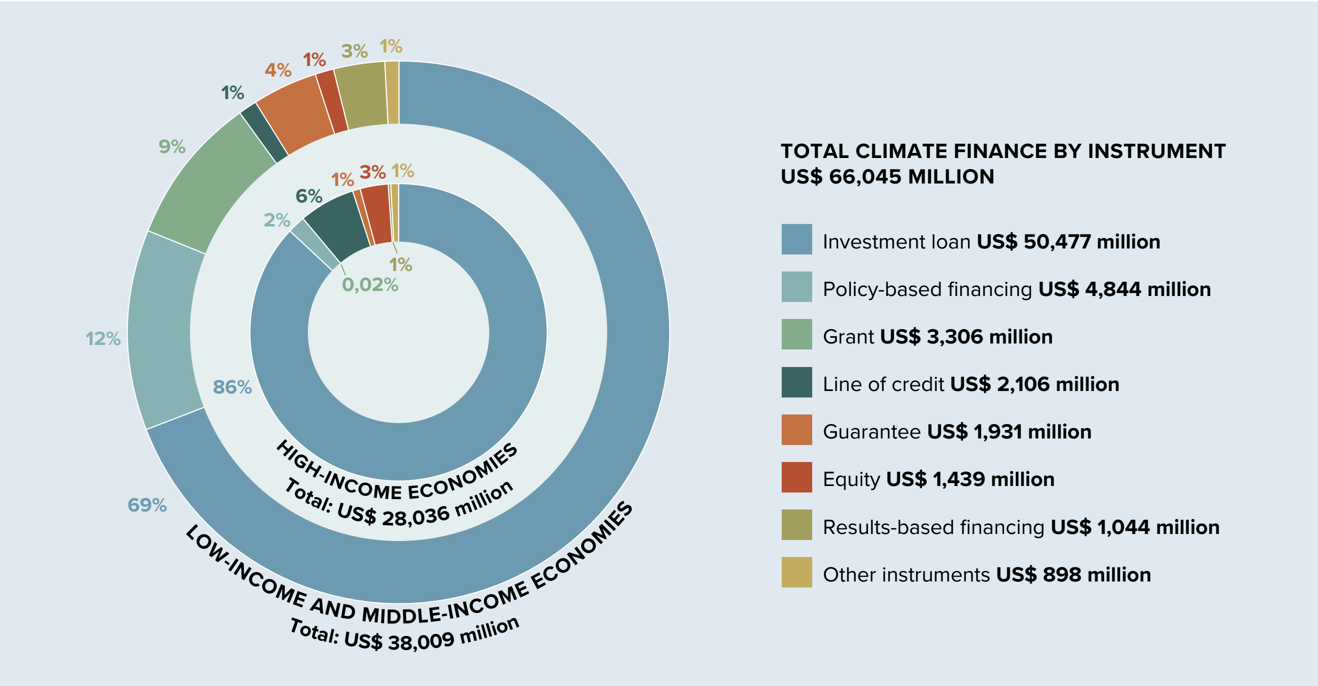
In total, multilateral development banks committed US$ 66 billion in climate finance in 2020. with approximately US$ 50 billion or 76 % of this total for climate change mitigation finance. The net total climate co-finance committed in 2020, together with the MDB resources, was US$ 85 billion, totaling US$ 151 billion.[viii]

Types of instruments used for climate-related transactions and facilitating access to capital: [viii]

- Concessional and non-concessional debt – Concessional (or soft) loans carry more generous terms than market loans. This can be reflected in below-market interest rates and grace periods that pause repayment requirements. Non-concessional loans are extended at, or near, market terms. (Loans can be sovereign or non-sovereign).
- Equity investments – Ownership interest in an enterprise that represents a proportional claim on the assets of the entity.
- International climate funds.
- Public-private partnerships.
- Grants – Transfers with no conditions for repayment.
- Loans – Covers operational or capital expenditures. Repayment required.
- Technical assistance – Risk-reducing activities provided to private and/or public project developers, governments and other applicable stakeholders. Technical assistance can be used to develop new markets or to mobilize finance, by supporting the creation of policy environments that are conducive to climate-resilient investment. [ix] Technical assistance can play a particularly valuable role for early-stage, higher risk initiatives—underwriting efforts to resolve barriers to investment.
- Results-based financing – Links disbursement of funds to measurable results.
- De-risking instruments – Help investors reduce or manage investment risks, typically in exchange for a fee, and thus improve the risk-return expectations of an investment. The main types of financial risk management products include: [x]
  - Guarantees – insurance and guarantee products safeguard investors from a borrower's failure to repay. A guarantee can be partial – protecting a portion of the investment through its lifetime, or back-end – covering the entire investment after a prespecified timeframe. Insurance and guarantees can be divided into three categories:
    - Political risk insurance/guarantee protects against the failure of a borrower to repay as a result of political events and circumstances such as governmental expropriation of assets, currency transfer restrictions or inconvertibility, breach of contract, war and other civil disturbances etc. Should repayments be disrupted due to such occurrences, political risk insurance/guarantees pay out all or a portion of the losses
    - Partial risk guarantees cover the risks of a local government failing to perform its contractual obligations in respect of a private sector project. These obligations are most often political or regulatory in nature
    - Partial credit guarantees support commercial borrowing for public investment projects by partially covering private sector lenders in the event of a debt service default by the local government
    - Lines of credit – a guarantee that funds will be made available.

T African Development Bank, Asian Development Bank, IaDB and IBRD could more than triple their spare collective lending capacity from US$ 415 billion to US$ 1.3 trillion if they moderately increased their leverage portfolio and

Figure 2. Total MDB climate finance by type of instrument, 2020[viii]



opted for AA+ credit rating – an approach taken by the New Development Bank (AA+ rated). The comparative experience of the New Development Bank in international capital markets is that there is a negligible difference in the funding cost of AA+ versus AAA.[xi] Development banks raise most of their funding on international capital markets by issuing bonds at cheaper rates than what developing countries can raise on their own—under this reasoning, the AAA rating has been assumed to be central to their business model.[xii]

Africa context

Africa contains 7 of the 10 most climate-vulnerable countries in the world.[xiii] In addition, nearly 600 million people in sub-Saharan Africa are without access to electricity.[xiv] These two points conspire to underscore the need for investment in implementing, scaling and replicating climate technologies in Africa. And it is estimated that the continent will require investments of over $3 trillion in mitigation and adaptation by 2030 in order to implement its constituent countries' NDCs.[xiii]

The counter to the climate challenge facing sub-Saharan Africa is that only around 3 percent of global climate finance flows into the region.[1]

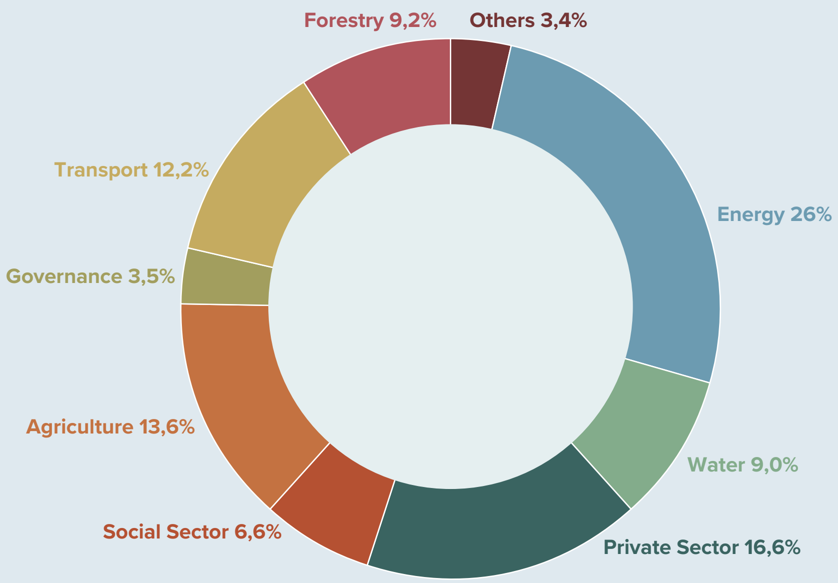
African Development Bank

The African Development Bank (AfDB) covers a large portion of its climate and low-carbon interventions through its Power, Energy, Climate and Green Growth Complex. AfDB invests (through equity and debt) in climate-related initiatives through instruments that include equity investments, guarantees and sovereign and non-sovereign loans as well as technical assistance. Some of the African Development Bank's investment cases have concessional contexts while others seek attractive financial returns that also ensure additionality and robust development impacts e.g. co-benefits to climate such as gender benefits and employments gains.

Recent AfDB climate finance milestones and commitments include:

[1] Remarks of the UN Secretary-General at the Leaders' Dialogue on the Africa COVID-Climate Emergency, April 2021; Note: this is also estimated as US$ 105 billion required per year to 2050 in order to align with development and climate goals in Sub-Saharan Africa (Global Renewables Outlook 2050, IRENA, April 2020)

Figure 3. AfDB climate finance sector breakdown (AfDB)



- In 2015 a USD 500 million green bond was issued by AfDB
- In 2019 AfDB lent USD 3.6 billion in climate finance
- Under the Climate Change Action Plan (CCAP) AfDB has committed to allocate 40 percent of approvals per year, cumulatively investing about USD 16.8 billion by 2022.
- The Bank's Climate Change Policy and new Climate Change Action Plan (2021-2026) has pledged USD 25 billion as climate finance to assist Regional Member Countries (RMCs) with the design and implementation of climate-friendly investments

The Africa Development Bank's focus on clean energy and climate is reflected across a number of initiatives including the New Deal on Energy for Africa, for which the overarching goal is to achieve universal access to energy in Africa by 2025. The New Deal is built on five inter-related principles: raising aspirations to solve Africa's energy challenges; establishing a transformative partnership on energy for Africa; mobilizing domestic and international capital for innovative financing in the continent's energy sector; supporting countries in increasing the Bank's investments in energy and climate financing; and increasing AfDB's investments in energy and climate financing.

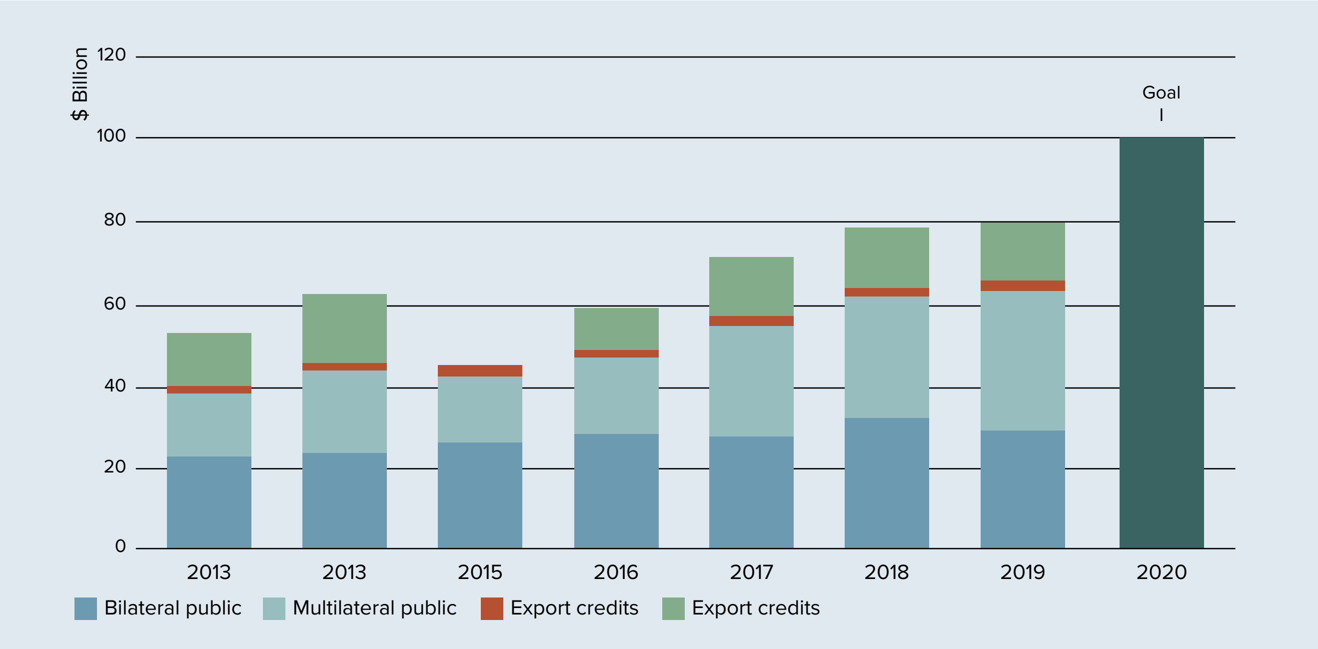
While the African Development Bank has an active track record in climate-related finance, it brings institutional standards and policy requirements to the funds in which it invests. These include environmental and social sustainability, governance, development results tracking and reporting, due diligence and funds' terms, consistent with best market practices.[xv]

Sustainable Energy Fund for Africa

Climate mitigation and clean energy funds provide channels for investment in projects through a mix of risk-mitigation activities and project preparation. The Sustainable Energy Fund for Africa (SEFA), a multi-donor trust fund, is managed by the African Development Bank. It is designed to provide catalytic finance that unlocks private sector investment. The Fund's project pipeline is developed through a combination of technical assistance and concessional finance instruments that resolve market barriers, reduce risks and leverage innovative approaches that yield bankable projects that provide access to clean, affordable energy.

There are three components through which SEFA operates. These include:[xvi]

Figure 4. Developed countries' pledge of US$ 100 billion to help developing countries tackle climate change[xxi]



- Project preparation –grants and technical assistance to project developers, helping to underwrite and facilitate pre-investment activities.
- Equity investments – this is generally early-stage capital, particularly for small-and medium-sized projects.
- Enabling environment grants – by providing support to public sector activities and agencies, these grants create and improve the context for private sector investments in sustainable energy.

SEFA's strategic priorities are:[xvii]

- Green Baseload: increasing the penetration of renewable energy in power systems, with a strong focus on power system stability, and delivering alternatives to fossil-fuel baseload generation options.
- Green Mini-Grids: accelerating electricity access to underserved populations through clean energy mini-grid solutions.
- Energy Efficiency (EE): improving the efficiency of energy services delivered through a variety of technologies and business models, also including clean cooking and pico-solar technologies.

A key characteristic of SEFA is its investment churn, i.e. turnaround time (estimated at 5-9 months[xvi]) and its capacity to administer all necessary due diligence and investment protocols; and invest. The Fund facilitated the scale-up of projects and programs and occupies a key role in the development of blended finance initiatives. These initiatives include the Africa Renewable Energy Fund, which stimulates and crowds in private sector funding through its strategic investments.

In 2020 SEFA funded seven projects for a total investment of approximately US$ 54 million. These projects included the COVID-19 Off-Grid Recovery Platform, the Africa Mini-Grid Acceleration Programme and the Algeria Renewable Energy Programme.[xviii]

SEFA is one of a number of vehicles in Africa designed to catalyze investment in climate mitigation interventions. The African Development Bank helped launch—and, along with myriad other entities, invests in—the Facility for Energy Inclusion, a financing platform for innovative energy access solutions in Africa. And the French Development Agency's Sustainable Use of Natural Resources and Energy Finance (SUNREF) initiative catalyzes commercial lending to the clean energy sector in developing countries. This initiative provides an integrated approach, offering structured finance to banks and their clients. It also offers technical assistance for companies in structuring their investments. And crit-

Figure 5. **Sources for finance for off-grid and mini-grid electricity 2018 (US$ million)**[xx]

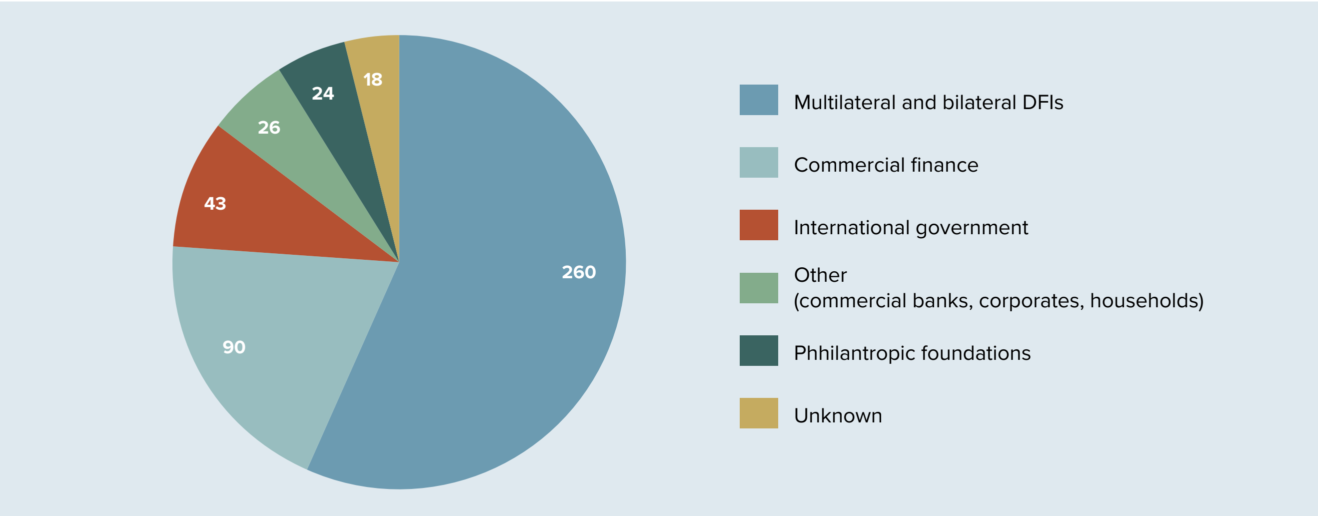
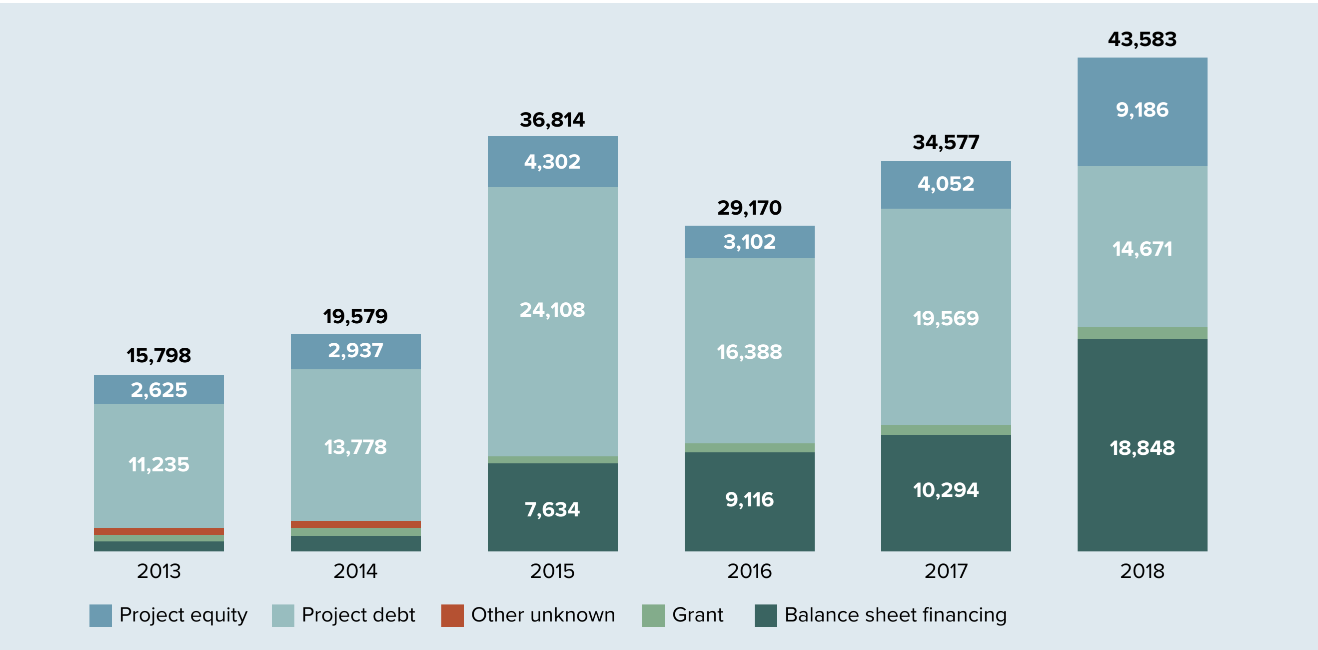


Figure 6. **Finance for electricity by instrument for selected developing countries**[a] **(US$ million)**[xx]



[a] High-impact countries for electricity: Angola, Bangladesh, Burkina Faso, Chad, Democratic People's Republic of Korea, Congo (DR), Ethiopia, India, Kenya, Madagascar, Malawi, Mozambique, Myanmar, Niger, Nigeria, Pakistan, Sudan, Uganda, United Republic of Tanzania, Yemen

ically, the initiative uses guarantee mechanisms to share credit risks of client banks that are developing renewable energy portfolios.[xix]

Financing gap

While the initiatives described above exemplify investment activities in clean energy and climate tech, significant funding shortfalls remain. Closing the financing gap for energy access in sub-Saharan African countries is estimated to require annual investment (up to 2030) of US$ 28 billion.[xix] Globally, required annual investment for residential electrification is estimated at US$ 41 billion.[xx] Meanwhile, the pledge of developed countries of US$ 100 billion annually in climate finance has not been delivered.

In 2018, majority of finance committed to off-grid and mini-grid solutions was dominated by bilateral and multilateral development finance institutions. Commercial and private finance represented about 25 percent.

Financing of electricity projects in developing countries is increasingly sourced through balance sheet financing and equity and consistently supported by debt instruments.

Private sector

The mandate for carbon-mitigating tech will undoubtedly require a massive government investment in related private companies. But governments alone will not be able to fund development of these technologies.[ii] The architecture of funding from international finance institutions, governments and public sources for climate-related projects is designed to catalyze private flows. In Africa, the mobilisation of private capital is critical to closing the financing gap for infrastructure, including clean energy.[xxii] And while firms such as BlackRock and Morgan Stanley are among a growing list of global investors expanding their climate tech-related portfolios, the specific needs and expectations of private investors need to be carefully considered when developing project opportunities, especially in emerging market contexts.

Private sector investment in climate tech and climate-transition projects comes in various forms (e.g. venture capital, equity, debt) and depends on an array of variables e.g. risk, expected performance, cost of capital and a range of indicators. Conventionally, private investment in emerging markets has responded to risks—where public sector financing would take-on high risks positions, enabling private-sector flows. But it is more complex than that and, in addition, as the costs of technologies has come down and markets have evolved, new opportunities have attracted private investment, particularly for funds with an ESG theme.

A key action in enticing climate finance flows from the private sector is taking up the risky tranches of an investment—a key action in making opportunities viable and attractive to private investors. One of the challenges is applying this model to smaller ventures that carry more risk by the nature of hitting remote end-users or last-mile link-ups. This is a function of understanding the decision-making criteria of private funds, private equity and venture capital.

Concepts and contributing factors—project unlockability

Core areas for ramping up investment in climate-tech and clean energy include (1) de-risking projects, (2) targeting projects that catalyze economic benefits and (3) investing in theme-adjacent initiatives.[xix] De-risking projects includes interrogating and resolving fundamentals such as regulatory reliability, technology performance, project costs as well as transactional elements such currency cover. Calibrating projects to drive demand, e.g. focusing on climate-aligned agriculture solutions such as solar irrigation betrays income generation value—an important consideration (from a commercial and impact perspective) for private investors. With respect to unlocking private finance, project scale (as well as other features such as securitisation for debt transactions) should be taken into account. Investments in green mobility, for example, is not restricted to small fleets of electronic motorbikes or micro-transport (e.g. rickshaws). This may also include infrastructure such as charging stations.

Emerging guidance continues to influence investment decisions on climate-tech opportunities and projects. These include:

- Creating and framing an impact thesis in complement to an investment thesis. Investments require a roadmap—a portfolio approach—it requires a lens to create conditionality and additionality.[xxiii]
- Structuring straighter pathways for private investment, e.g. through timely exits (i.e. in equity transactions). For example, in East Africa where off-grid energy markets are relatively more developed than other regions of Africa, “the lack of exits keeps later-stage commercial investors, who look for exits as proof points, on the sidelines.”
- These later-stage commercial investors are pivotal to providing target companies with the capital needed to reach scale and expand into new markets and grow their off-grid customer base.[xxiv]
- Executing feasibility studies reflecting technology, emissions, environmental impact, gender inclusion, cash flow scenarios and other investment priorities:
  - Viable investment time horizons and tenors – in broad terms, commercial investors in climate tech in emerging markets do not adhere to the terms of ‘patient capital’ that development finance institutions do. For

example, commercial investors may consider 5 years to be a maximum investment window whereas development finance institutions may consider 10 years to be reasonable.

- Scalability – reflects the prospect of increasing revenue opportunities without undertaking major additional costs
- Cost of capital – this is the cost of debt and equity required to finance a project and an assessment of the company operating the climate-related project. This is a major consideration of investors. Investment returns will need to exceed this figure (i.e. the hurdle rate).
- Transparency – commercial investors require transparency which is a product of a strong enabling environment. This related to openness and reliability of regulatory measures and policies, project stakeholders and data, as well as factors such as ESG metrics.

Space for innovation

Climate tech was once considered a natural candidate for venture capital (which is a form of private equity attuned to start-up and early-stage enterprises). Funding for (primarily Silicon Valley) startups in the cleantech sector fell from US$ 5 billion in 2008 to US$ 2 billion in 2012.[xxv] But many of the targeted businesses did not survive and the 'bubble' burst. One of the main reasons the dynamics did not work is that cleantech did not match the venture capital model such as the high research, development and demonstration costs and relatively long development cycles of climate technologies.

Consequently, there is a need for patient, non-exit driven, strategic financing that is outcomes or results-based.[xxiii] This type of funding can come from government sources or technical assistance, which can be packaged in interventions by development finance institutions. And through this tier of investment, projects can be de-risked and stress-tested which, in turn, opens them up to private financing, which relies on practical financial measures and viable risk/return mechanics

Key takeaways

This paper is not an argument that given space and room, markets will self-organize around climate tech opportunities. Rather, climate finance for clean technologies in fragile and emerging markets requires a blend of public, often patient and risk-accepting, funds as well as private capital. Some instruments are more suitable than others for investment depending on the contours of the scenario, i.e. technology, market and other variables.

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