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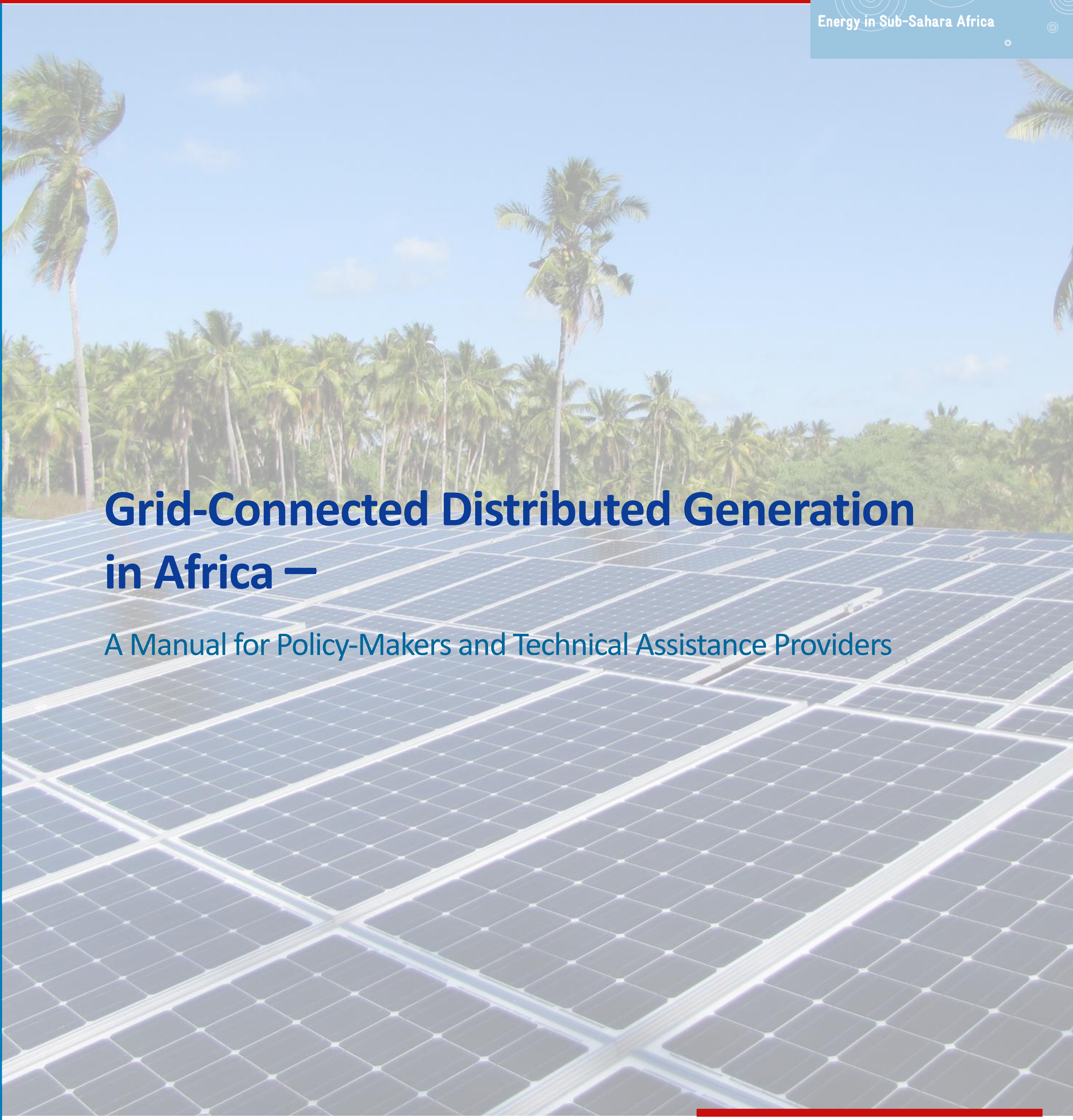

Grid-Connected Distributed Generation in Africa –

A Manual for Policy-Makers and Technical Assistance Providers

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SAGEN
SOUTH AFRICAN-GERMAN ENERGY PROGRAMME

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About SN Energy SSA

The SN Energy SSA is a network of energy programmes of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The mandate of the sector network is to facilitate technical knowledge management and exchange amongst GIZ energy programmes in Sub-Sahara Africa.

About GET.transform

GET.transform is a technical assistance programme which supports national and regional partners and institutions in advancing their energy transitions. The programme is supported by the European Union, Germany, Sweden, the Netherlands and Austria. For more information, please visit: www.get-transform.eu

About SAGEN

The South African-German Energy Programme (SAGEN) is part of the bilateral collaboration between South Africa and Germany. SAGEN is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ and collaborates with South African partners from government and the private sector to promote a diverse and inclusive energy transition for all. For more information, please visit: sagen.org.za

About RMS

The Project Strengthening the Market for Solar Power in Tunisia (RMS) is part of the bilateral collaboration between Tunisia and Germany. RMS is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and collaborates with Tunisian partners from the public and private sector to promote the development of a sustainable market for decentralised photovoltaic systems.

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List of Abbreviations

AC	Alternating Current
ANME	Tunisian Agency for Energy Management
APIA	Tunisian Agency for the Promotion of Investments in Agriculture
BMZ	German Federal Ministry for Economic Co-operation and Development
CTAA	Tunisian Technical Centre for Agrifood
DMRE	South African Department of Mineral Resources and Energy
DPV	Distributed Photovoltaics
DRE	Distributed Renewable Energy
GIS	Geographical Information System
MARHP	Tunisian Ministry of Agriculture, Water Resources and Fishing
MIME	Tunisia's Ministry of Industry, Mining, and Energy
NERSA	National Energy Regulator of South Africa
PV	Photovoltaics
SAGEN	South African/German Energy Programme
SSEG	Small-Scale Embedded Generators (DREs in South African context)
STEG	Tunisia's National Electric and Gas Utility Company
UTAP	Tunisian Union of Agriculture and Fishing

1 Introduction

Distributed Renewable Energy (DRE) provides African countries with an opportunity to decarbonise their electricity grid, reduce their dependence on imported fuels, create new economic activities, and increase the democratisation of energy. With decreasing DRE prices, electricity consumers are eager to adopt DRE as a way to manage their energy costs and be a part of the clean energy transition. Although DRE markets are at varying levels of maturity throughout the continent, most African countries are looking to facilitate the deployment of DREs safely and equitably.

The development or strengthening of DRE markets requires considering a broad array of technical, regulatory, and economic considerations to ensure their sustainability. Technical assistance providers – whether they be international organisations, such as GIZ, consultants, or other subject-matter experts – can be uniquely positioned to implement a diverse set of support activities, helping develop sustainable DRE markets and building consensus and capacity amongst stakeholder groups.

In this manual, GIZ highlights actions that technical assistance providers can take to develop favourable conditions for DRE deployment in Africa. The manual's primary purpose is to serve as an introductory reference document for technical assistance providers looking to implement DRE projects in Africa – many of the themes covered here are globally applicable, however. Recognising the diversity in economic conditions and unique political climates, this manual identifies themes that cut across these differences and focuses on three principal areas of support and analyses:

- **Technical.** Technical assistance providers can support countries in developing or enhancing their technical requirements for interconnection of DREs. Analyses can inform how the electric grid may need to adapt to increased levels of DREs (for example, integration studies at the bulk power level or hosting-capacity analyses at the distribution level).
- **Regulatory and policy**. Setting-up a robust regulatory structure for DREs facilitates their deployment and technical assistance providers can be instrumental in supporting governments in the creation or strengthening of regulations and policies. DRE-focused projects can help match procedures to policy goals and cultivate a culture that encourages transparent and rigorous analyses to inform DRE regulation.
- **Financial and economic**. Technical assistance providers can have a role in promoting economic analyses to support informed, evidence-based DRE policy-making. Developing analytical methods and financial analyses that are transparent, reproducible, and based on the local context is key to creating a common understanding of the economic issues related to DREs. Consensus amongst DRE stakeholders can lead to more equitable outcomes.

The manual also highlights a variety of case studies from GIZ activities in Tunisia and South Africa describing some of the projects – their objectives, methods, and outcomes – that have been undertaken in these three areas to share some of the GIZ experiences on these topics.

In this document, we define DREs as any energy generation that rely on renewable energy sources, are interconnected to the electricity grid, and are installed behind the customer meter.

Although there is a diversity of technologies that fit this definition, including distributed photovoltaics (DPV), micro-hydro, small-scale wind, biogas generators, the vast majority of DRE deployment in Africa thus far has been DPV. Thus, this document will primarily focus on DPV, although many of the regulatory, technical, and financial assistance and analyses are equally applicable for the other technologies that have thus far been deployed mostly in technology pilots or niche applications. As battery costs continue to decline, behind-the-meter DREs will increasingly be co-installed with battery storage systems to enhance resilience and electricity bill savings for adopters; analyses will increasingly need to account for DRE customers co-adopting battery storage systems. The primary objective of DREs is often to produce electricity that is to be self-consumed by the host customer although, in many cases, excess electricity is injected into the electric grid to be consumed by other electricity customers on the same distribution feeder. Regulations and codes can drive how much electricity is self-consumed vs. injected into the grid, through financial incentives and technical limits.

Renewable energy technologies, whether centralised, distributed, or off-grid, will play a role in the modernisation and decarbonisation of the electricity grids in Africa. Benefits of renewable energy sources for electricity generation are diverse and well-documented (e.g. [1]). In addition to those benefits, DREs can play a role in addressing a number of the challenges faced by the electricity sector in diverse country contexts, including volatile electricity generation costs, poor electricity reliability, high transmission and distribution losses, local health impacts, reliance on imported fuel sources, and capital constraints on investment.

2 Understanding DRE Market Stages Help Determine Support Options

Regulatory frameworks to support DREs among countries on the African continent are diverse. Over time, some countries have developed a robust set of rules and regulations that allow for interconnection onto the grid, whereas other countries are in the beginning stages of establishing DRE regulations to enable interconnection of DREs to the electricity grid[1]. As such, activities to support the development of DREs can differ substantially from one country to the next. This document introduces three DRE development stages: early, mid, and mature stages. Each stage has distinct support opportunities for technical assistance providers. However, some countries may not fit neatly within one of the three stages described below, and more than one may be applicable.

2.1 Early stage of DRE development

Countries that are in the 'early' stage of DRE development have little or no deployment, a nascent local industry, in large part due to a lack of regulations that enable interconnection of DRE technologies into the grid. There may be isolated residential, commercial, or industrial customers that install DRE systems regardless of the lack of legal structures to do so, but deployment is not sufficient for a local industry of suppliers and installers to blossom. With continued cost reductions in DRE technologies, unregulated and informal DRE industries could emerge, with deleterious effects on grid safety, security, the financial well-being of electric utilities, and ratepayers. It is in the self-interest of nations to put regulations for DREs in place to avoid such negative impacts, regardless of its views on renewables being a key growth area. Support analyses and activities are valuable to assist governments in deciding how to proceed with the establishment of new policies. These include understanding the technical and economic potential for DRE technologies, including mapping and sector analyses; adapting best practices for interconnection rules and standards to the local context; providing regulatory support by presenting options for DRE integration; training and workshops to develop local DRE technical expertise for suppliers and potential installers; information campaigns to inform the public about DRE technologies and how they could benefit from investing in DREs.

[1] The African Development Bank's Electricity Regulatory Index Report 2020 [2] found that 42% of countries in Africa had yet to develop policies for not yet developed guidelines, or general policy documents for the systematic development of renewable energy.

Developing the right regulatory support policies for DREs in early stage DRE markets does not necessarily imply subsidies for DREs. In the past, many countries had chosen to subsidise DREs to help establish the market and some have done so through the regulatory process, with recent price reductions; however, some governments are choosing not to provide any financial subsidies for solar, relying on market forces to develop the local industry. Regardless, government commitments and regulatory stability is necessary to provide sufficient assurances for a local industry to flourish. Ambiguous or 'stop-go' policies can create too much uncertainty for investors and companies to enter the market, leading to low levels of DRE deployment; third-party support from technical assistance providers can assist in the creation of clear guidelines and integration of DREs into energy resource planning and sustainable market growth.

Rigorous analysis is also helpful to give various stakeholders confidence in the development of DREs. For example, electric utilities may push back against government policies that support DREs, due to anticipated technical and financial risks. Technical and financial analyses can help alleviate concerns if results indicate lower than expected DPV impact. For example, utilities may be concerned that the introduction of DREs on their distribution feeders may result in reverse power-flows, voltage mismanagement, or increased infrastructure wear-and-tear. Technical assistance providers can develop analysis programs whose results may alleviate these worries. For example, these could include assisting the local energy ministry in the development of codes and standards requiring smart inverters to control (and sometimes even help with) voltage control issues, as well as performing and training in-country experts on hosting capacity analysis, which enables utilities to determine how much solar can be accommodated on distribution feeders without adverse effects. Another example would be supporting the national energy department or ministry in developing financial impact analyses for various DREs, which would enable a richer and fact-based discussion on potential concerns about cost shifting from residential non-DRE customers to DRE customers.

2.2 Mid-stage of DRE development

The setting-up of rules that allow the interconnection of DREs have helped countries in the early stage of DRE development expand their domestic DRE market in the last few years, but such countries – that are now in the mid-stage of DRE development – can find great value in a different set of support analyses and activities to further bolster the integration of DREs in their national electric grids. Even DRE support policies that have helped achieve previous national goals can benefit from reforms and revisions given the fast-changing DRE technologies, their declining costs, and the countries' evolving policy goals. For example, a government which had decided to initially subsidise distributed solar to encourage adoption and reduce local costs through local economies of scale five years ago may re-think and refresh their support policies to reflect new pricing and policy landscapes. Simple policies to encourage DRE adoption (e.g. net energy metering) can be effective during the early stage of DRE development, but may no longer be appropriate during the mid-stage of DRE development (e.g. when cost shifts from net metering are seen as unsustainable at higher DRE penetration levels). The nature of the regulatory support often changes as DRE markets mature; the focus is no longer on assisting in setting basic regulations and processes enabling the integration of DRE into the electric grid; instead, the focus is on changes or refinements to the existing practices. In some cases, these changes can be the result of a changing industry landscape (e.g. reduced DRE prices may indicate that subsidies are no longer necessary), changing priorities (e.g. enhanced support mechanisms may be necessary to achieve more aggressive government DRE targets), changing deployment levels (e.g. higher levels of DRE on the grid have precipitated new technical, financial, equity, or policy-related challenges), or some combinations of these.

2.3 Mature DRE markets

Mature DRE markets have significant deployment levels with advanced policy frameworks to support the integration of DREs into the grid to benefit public and private stakeholders. Countries with mature DRE markets often have a rich domestic ecosystem of experts within public, private, and non-profit organisations to support all aspects of DRE integration and deployment. These local institutions can provide much of the regulatory support for DREs, including monitoring technical and financial integration through country-wide or regional integration studies, financial impact analyses, introduction of complex rate designs, DRE integration through smart grid capabilities, and infrastructure analyses. Most countries approaching mature DRE markets are in more industrialised nations, and arguably, few nations (and no African nations) have achieved this level of DRE market development, hence this document will not focus on technical, economic, and policy support options for countries with mature DRE markets. Noteworthy, too, is that although a country may have a mature market for a specific DRE technology, it may be at an earlier stage for other DRE technologies, and thus, in most countries, there are often opportunities for institutional support for some DRE technologies.

Stages in DRE Development

Stage	Early	Mid	Mature
Description	Little to no DRE deployment Few DRE installers Few regulatory frameworks to enable DRE interconnection	Local installers No electricity infrastructure upgrades necessary Broad, simple support policies sufficient Supply and demand remain largely unaffected.	Widespread adoption of DRE technologies
Support Analysis and Activities	Solar insolation maps DRE potential studies Interconnection rules and standard development Regulatory support Trainings and workshops for installers Information campaigns to build awareness	Regulatory support Financial impact analysis Integration studies Hosting capacity analysis Equity and access considerations	Regulatory support Complex compensation mechanisms Cost-reflective rate design for DREs Infrastructure analysis for saturated feeders

FIGURE 1: Stages in DRE Development – Summary

43 of the 50 countries with the lowest electrification rates globally are on the African continent. As of 2019, an electrification rate in sub-Saharan Africa of only 48%, with North Africa faring better with close to 100% in all countries with the exception of Libya (70%), as per the World Bank's DataBank [3]. Renewable energy potential on the continent is significant, as is its potential for social, economic, health and environmental gains [4]. Distributed electricity generation has received some attention from policy-makers – an increasing number of African countries are including DREs in their strategic plans (including seven in West Africa, six in East Africa, all five countries in North Africa, and two in Central and Southern Africa). Early efforts focused on off-grid solar home systems, with markets emerging over 20 years ago in East Africa, for example; however, these solutions are often limited to lighting and low-power applications, limited by battery storage-size due to high costs. Development of mini-grids is expanding, but renewables are not always central to these efforts. At least nine African countries have implemented national net-metering or net-billing policies, allowing customers to interconnect solar or other DREs on the customer-side of the meter in order to reduce their electricity bills. Other countries allow solar interconnection, but do not currently compensate exports into the grid (e.g. Ghana). Feed-in tariffs have been implemented for renewables in 14 African countries, but these have mostly focused on large scale installations. Financial incentives for DREs have been implemented in over 25 African countries, in the form of tax holidays (more common) and direct subsidies (less common). A number of countries are currently considering new regulations (e.g. Zambia has released net-metering draft regulations and Ghana is considering net-billing policies, as of September 2022).

The majority of countries on the African continent have very low levels of distributed renewable deployment ([5], [6], [7]) and are in the 'early' stage of DRE development. Although the reasons for such low levels of DRE deployment are diverse, many countries may not have the minimum set of regulations to enable electricity consumers to interconnect a PV system behind their electricity meter to the utility's electric grid, a minimum requirement for developing a DRE market. Given that other African countries have already done the legwork in respect of selecting and developing DRE regulations, sometimes with support of technical assistance providers, there are a number of knowledge exchange opportunities. In discussing the various options to best support countries in achieving their DRE goals, this document will highlight some activities GIZ has led on the continent through case studies, with a focus on DRE activities in Tunisia and South Africa.

Box 1. Technical Working Groups: A Model for DRE Support Activities

In order for support activities to enable sustainable transformations in the DRE market, capacity-building and stakeholder buy-in must be integral to the support project. Rigorous analytical methods using high-quality data inputs can lead to evidence-based recommendations which can be pivotal to advancing the DRE landscape. However, if local knowledge and skills are not developed concurrently, the methods are unlikely to be integrated into local practices of knowledge management and planning, resulting in unsustainable support activities. To ensure an enduring transfer of knowledge, the implementing experts can conduct any necessary analysis in conjunction with a working group that includes staff from organisations who would make use of the outputs, and who have the proper background and skills to be able to replicate the work in the future. This creates more opportunities for two-way knowledge transfer, ensuring that the methods used are appropriate to the local context. Local regulatory and technical staff who participate in workshops, led by international experts who look to develop trusting relationships, are more likely to be the champions of the ideas and concepts on-hand and to develop personal accountability and responsibility, thus increasing the chances of sustaining institutional changes.

DRE support activities very often cut-across several areas of expertise, which can be found among energy regulators, ministries and government agencies, electric utilities, rate-payer groups, the private sector, and civil society. Working groups also provide an opportunity for these groups, who may not typically work together, to better understand each other's perspectives on DREs and to learn from each other. The transparent methods and data used within working groups also allows its members to validate the work, which makes it easier to agree on follow-up action. For example, if the electric utility and the energy ministry agree on a range of the revenue impacts of DRE on the utility, it eases negotiations about compensation mechanisms – which drives the revenue impacts from DRE—as all the stakeholders from the working group have agreed on the underlying analysis methods and validated results.

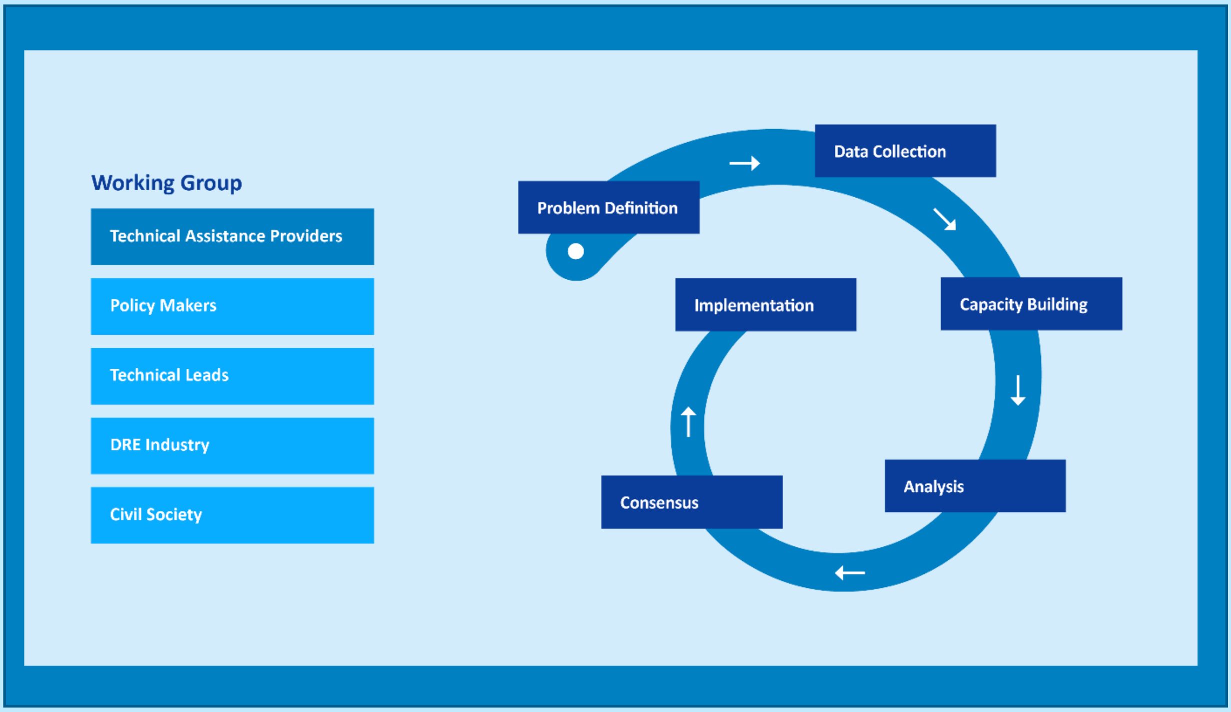

FIGURE 2: Working groups: Technical assistance providers facilitating the process from problem definition to policy implementation

Box 2. An Overview of South Africa's DRE Policy and Market Conditions: Context for the South Africa Case Studies

In November 2017, the South African Department of Energy paved the way for the interconnection of decentralised renewable energies, with a capacity of no more than 1 MW, referred to as Small-Scale Embedded Generation (SSEG[2]) by repealing the licencing requirement for such systems, hence simplifying the interconnection process.

As in many countries, the decreasing capital cost of PV systems, combined with increasing electricity tariffs, are driving the demand for DREs. Additionally, South Africa is experiencing an energy crisis with load-shedding (i.e. rolling blackouts) having to be implemented ever more frequently in order to prevent the system from instabilities. Load-shedding is further increasing the demand for PV plus storage to provide supply during blackouts. In total, it is estimated that, by the end of 2021, approximately 1,500 MW of rooftop PV systems will have been installed [9].

The increasing interest in DRE deployment by residential, commercial and industrial customers is, however, met by already struggling distribution companies. Approximately 55% of the end-customers in South Africa are serviced by 165 municipal distributors. The remaining customers are supplied by the distribution division of the national utility, Eskom.

Municipalities have used electricity sales as a revenue generator to cross-subsidise other services in the past. Increasing wholesale tariffs and an ageing infrastructure has led to an increasing number of municipal distributors with financial losses. Consequently, the prospect of losing revenue due to customers generating their own electricity has led to the municipalities resisting support policies for DREs. Additionally, most municipalities are struggling with limited human capacity to assess interconnection applications, to manage more complex metering and billing, and to plan the grid for changing consumption patterns.

There are two other main decision-makers for DRE policies and regulations: the Department of Mineral Resources and Energy (DMRE) and the National Energy Regulator of South Africa (NERSA). While the DMRE paved the way by repealing the licencing requirement for systems up to 1 MW in 2017, and then expanding the licencing exemption to generators with a capacity of up to 100 MW in August 2021, it does not provide much guidance on, or support with, the practical implementation. Similarly, NERSA has introduced a registration system that is fairly complex. Although there have been several ideas for streamlined processes over the years, and a standing offer of technical support from the German Federal Ministry for Economic Co-operation and Development (BMZ) funded South African/German Energy Programme (SAGEN), there has not yet been a simplification of the interconnection process as of September 2022.

The lack of policy and regulatory guidance has led to a large range of DRE support policies across electricity distributors depending on the individual distributor's progressiveness and initiative. In order to support municipal distributors, SAGEN, together with the South African Local Government Association and supported by the DMRE, had set up the Municipal SSEG Support Programme. Implemented by Sustainable Energy Africa and the Energy Centre of the CSIR. This programme offered hands-on support to municipalities on all aspects of SSEG integration. The South Africa case studies included in this document all describe work from this programme.

[2] This document will use SSEGs in South Africa and DREs interchangeably.

3 Technical Support and Analyses

This section highlights how technical assistance providers can assist regulators and decision-makers in the development and strengthening of DRE regulations and programmes.

3.1 Technical potential studies

Quantifying the magnitude of the DRE resources available in a country is often one of the first analytical exercises undertaken as a government develops DRE targets and support policies. This includes developing an understanding of the underlying renewable resources, such as solar radiation or wind data, in the respective country. This can be done at various temporal and spatial scales. These studies often rely on GIS mapping, showing various resource characteristics on a map of the country or region, but can also include data at a much higher temporal resolution (e.g. 15-second solar radiation data for a specific site). There are several global renewable resource data models that can be used as a first approximation, developed using complex methodologies making use of global topological and climate data (e.g. PVGIS, Global Solar Atlas). These models can be validated or calibrated with locally collected data, which may require working with local meteorological agencies or setting up specialised ground measurement equipment including pyranometers (to collect solar irradiance) or anemometers (to collect wind speed and direction). In most cases, with the exception of the smallest countries, the domestic technical potential for renewable energy surpasses its electricity needs (e.g. [8]). Although such an analysis can provide the confidence needed for policy-makers to develop renewable energy targets, further analysis can inform the potential for DRE deployment, in particular. For example, simpler analyses could make use of data on the existing building stock to make estimates on how much solar could be developed. More advanced analysis using lidar data and GIS methods allow for more detailed understanding of rooftop solar potential [10].

3.2 Laying the Ground Work: Technical codes and standards

There are a number of foundational rules and regulations as regards technical codes and standards that need to be in place for the development of a DRE market. These include rules to determine proper DRE system designs, specifications, and interconnection to ensure they are safe and reliable, as well as electric grid standards which can safely accommodate the higher penetration rates of DRE technologies. Most countries have adopted codes and standards for the electric grid and general construction for buildings, but these may not include specific DRE technologies. In other cases, the codes and standards that were established in the past are outdated and have not been updated with advances in DRE technology, or to accommodate higher levels of DREs. Either way, there is a wealth of resources for countries to make use of, as the objectives for DRE codes and standards are relatively consistent from one jurisdiction to another, and thus materials developed for most country contexts can be relevant. There are a number of international organisations which have developed a wide range of standards for DRE equipment, system design, and electrical codes (e.g. the International Electrotechnical Commission), interconnection (e.g. the Institute of Electrical and Electronics Engineers), and building codes (e.g. the International Code Council).

Technical codes and standards tend to focus on ensuring that DREs are safely interconnected to the grid and should ensure that DRE systems can appropriately respond to grid conditions and instabilities, either by shutting-off, or providing corrective actions. Newer standards, e.g. IEEE 1547-2018, introduce a number of interoperability requirements such that components can exchange and make use of grid data; more recent equipment, in particular inverters which convert DC power from solar photovoltaics or storage systems to AC power synced to the bulk power system, can meet requirements set by these standards. In some cases, the regulator can maintain a list of approved equipment to ensure that all the equipment used is compatible with the selected grid code (e.g. the California Energy Commission's Solar Equipment List). With the pressures of cost reduction, some systems can be plagued with issues related to the poor quality or performance of the equipment (poor quality of installation will be discussed later in this document). By maintaining a list of approved equipment, regulators can also address some of the issues related to DRE-system quality and performance.

Given the number and complexity of the standards available for DRE-system design, grid support and interconnection, technical assistance providers, who help government officials, regulators, electric utilities, and local experts navigate the DRE codes and standards, would accelerate the process of setting appropriate codes and standards given the local context. This could include summarising the available international codes and standards, presenting case studies from other countries, along with potential best practices and lessons from countries in various contexts, and facilitating the selection of DRE codes and standards and their integration into existing grid codes. As new technologies emerge, and with increasing levels of DRE penetrations, regulators may want to periodically review and potentially update their standards. Deciding on a particular standard for DRE equipment and grid codes requires input from a wide variety of stakeholders, including state governments, energy regulators, electric utilities, equipment manufacturers, ratepayer groups, and the DRE industry, inter alia. This stakeholder process can be arduous and complex and can benefit from facilitation by neutral outside groups, such as GIZ or other international organisations with expertise in DRE standards and codes.

Box 3. TUNISIA CASE STUDY: Standardising the Technical Requirements for Solar PV

Technical specifications are essential to the development of standardised DRE project approval and interconnection procedures and thus help enhance the quality of DRE systems and ensure their sustainability. In 2021, as part of the bilateral project entitled 'Strengthening the market for small and medium-sized PV projects', GIZ, the Tunisian Agency for Energy Management (ANME), and the national electric utility (STEG) developed technical references for the various applications of photovoltaic (PV) plants. Several working groups were created to develop these technical requirements, and to simplify and harmonise the procedures regarding the approval of PV projects and their interconnection. With ANME, three technical specifications were first developed in 2018, and updated in 2021, for isolated, off-grid applications, including public lighting, solar pumping, and rural electrification. With STEG, two technical specifications were issued for grid-connected PV plants, namely those connected to the low-voltage grid (developed in 2018, and updated in 2021) and the medium-voltage grid (developed in 2021).
It became clear that updating the technical specifications and project approval procedures was necessary after STEG technical staff had noticed that relevant technical details or normative requirements were not sufficiently taken into consideration during commissioning inspections. After updating the technical specifications in 2021, GIZ organized trainings for STEG staff, engineering consultants, providers and installers of off-grid PV systems in order to familiarise them with the newly-established norms.

Thanks to these technical references, PV system installers, as well as STEG staff responsible for grid connection, can follow a step-by-step, formalised installation process aimed at simplifying the interconnection, hence boosting DRE deployment, whilst ensuring the installation of high-quality systems. These documents are publicly available online (see links below), thereby ensuring a greater transparency of the technical requirements for PV deployment.

STEG: Technical reference LV grid
ANME: Technical references for off-grid applications

3.3 Hosting-Capacity Analysis: Understanding the limits of DRE on the distribution grid

Utilities and regulators are sometimes wary of integrating DREs onto the grid without knowing how much DRE can be interconnected to the grid before grid violations occur, operation at unauthorised frequencies or voltages, or causing damage to distribution equipment. These hesitations can cause utilities to oppose DRE development in their grid. Case studies, analysis, and rules-of-thumb developed in the European or US context do not always reassure utilities given the very different investment context in some countries, and the impression (correct or not) that the grid in some countries is not built with the same resiliency. DRE hosting-capacity analyses can help address this lack of information and provide some level of reassurance to utilities and regulators. These analyses determine at how much DRE capacity can be supported on a distribution feeder before necessitating an infrastructure upgrade.

These analyses require a minimum amount of data on the distribution infrastructure topography and load distribution and can range in complexity from simplified, static analyses, which consider worst case voltage scenarios with strict grid rules, to more complex, dynamic analyses, which consider temporal elements of load and DRE generation profiles, as well as the timing and duration of potential grid violations. The latter is more data, time, and cost-intensive as it requires the collection of data which may not have been previously collected by the utility, and the training of staff to use specialised software products; however, these more involved analyses can provide more realistic assessments of how much DRE can be integrated into specific feeders, particularly with the integration of smart inverters which can respond to grid conditions. The dynamic hosting-capacity analyses require software platforms that are either commercial products (e.g. PSSE, Synergi, CYME, Milsoft, PowerFactory), or open source (e.g. OpenDSS). The analysis can use data from a few, representative distribution feeders, or can target specific feeders where DRE deployment is likeliest to be most significant, given market studies. Technical support providers can assist in determining which analysis is most appropriate when given the DRE deployment levels and budget/time allocated to the project. These support projects are most effective when implemented as hands-on training and workshops with technical staff from utilities, and industry participants (i.e. working groups – see Box 1), as this type of analysis is not a one-time effort. These analyses need to be replicated periodically as grid conditions, codes and standards, as well as DRE technologies evolve, and as utilities collect more refined temporal data with the advent of the smart grid, data analytics capabilities, and advanced metering infrastructure.

Complementary to hosting-capacity analyses are the introduction of mitigation strategies to bolster the resilience of the electric grid for increased DRE penetrations. Projects focusing on mitigation strategies are probably only relevant for countries in the mid- and mature-stages of DRE development, as grids with low penetrations of DREs are unlikely to require any mitigation strategies since most grids can reliably integrate low levels of DRE technologies, regardless of the local conditions of the infrastructure (simpler hosting-capacity analysis can confirm this).

Box 4. TUNISIA CASE STUDY: Establishing a Grid Code and Training the Utility to Conduct DRE Hosting-Capacity Analyses

Higher shares of DREs in the electricity mix can pose a challenge to national grid stability if not properly managed, mostly a result of their intermittency. Grid codes help minimise any instabilities by defining technical parameters which a power-producer must meet in order to interconnect to the grid. Establishing a grid code helps ensure the efficient integration of distributed variable renewable energy and reassures different stakeholders that the grid will remain stable with higher levels of DREs.

Since 2016, after the enactment of Tunisian Law No. 12-2015 pertaining to the production of electricity from renewable energy, GIZ has been supporting the national electric utility (STEG) in the creation and updating of the Tunisian grid code, including detailed instructions and the necessary steps for the STEG agents who are responsible for verifying the compliance of facilities during the approval and operating phases.

Several stakeholders were involved in establishing the Tunisian grid code, including the Ministry for Industry, Mining and Energy (MIME), STEG, and the private sector. Rather than starting from scratch, the first step was to study grid codes established in other countries and to then adapt those most suitable to the Tunisian context. The first version of the grid code was subject to a public consultation in order to involve all the stakeholders concerned from the public and private sectors. After modifications resulting from the public consultation, the grid code was implemented on an order from the MIME in February 2017. In order to continuously improve the legal framework on the connection and operation of RE-based electricity generation projects, an update of the grid code was initiated with GIZ in January 2022.

The integration of VRE into the grid also required capacity-building for STEG technicians in order to calculate the maximum DRE penetration rate (i.e. the hosting-capacity), to conduct flexibility analyses, and to determine any necessary reinforcements to the electrical grid. To this end, GIZ assisted STEG in setting-up the necessary short-term studies (through 2025, with business-as-usual and renewable energy programme implementation scenarios), in order for STEG technical staff to develop the necessary skills to enable them to carry out these analyses themselves over different time horizons. GIZ provided training on digital power-system analysis tools, such as DigSilent's PowerFactory and Siemens' PSSE software tools, which are used for hosting-capacity analyses and DRE integration modeling.

Box 5. SOUTH AFRICA CASE STUDY: Support for Grid Impact Studies and Hosting-Capacity Analyses

Although South Arica has developed comprehensive technical standards and guidelines for the interconnection of DREs, most notably the NRS 097 series entitled 'Grid Interconnection of Embedded Generation', Part 2 'Small-Scale Embedded Generation', and Section 3 'Simplified utility connection criteria for low-voltage connected generators', many municipal distributors have faced challenges in applying these technical standards and guidelines.

Consequently, GIZ's Municipal DRE Support Programme includes extensive training on the NRS 097-2-3. Additionally, as part of the programme, three municipalities received additional support on detailed grid impact studies and hosting-capacity analysis. The core of the work package was to provide training to these three municipalities in establishing a process for doing grid impact studies (manual calculations, as well as software simulations using PowerFactory). Following a gap analysis of the existing processes and capacities, SAGEN developed and implemented customised training programmes for each of the municipalities.

The gap analysis found that the municipalities would benefit from a simplified load-flow assessment tool which incorporates South African requirements (e.g. Grid Codes, NRS 097 series). This tool was developed in Microsoft Excel and can be implemented in all the municipalities. Additionally, SAGEN helped develop a hosting-capacity analysis tool, implemented in DigSILENT PowerFactory, in response to a request by the City of Cape Town to achieve a more detailed understanding of the parts of their electric grid most prone to DREs. In order to give all South African municipalities the opportunity to benefit from this work, the results were summarised in the SSEG Technical booklet – Grid impact assessment for municipalities and presented at a virtual municipal road-show event.

The gap analysis showed that technical capacity was a challenge in implementing DGE programmes, even for some of the more advanced municipal distributors. The lack of technical skills will make it challenging for most municipal distributors to be able to execute advanced gird impact studies in the near to medium future, thus potentially stalling DRE deployment. Furthermore, all three of the municipalities which participated in the SAGEN training had limited data on their low-voltage networks and parts of their medium-voltage networks. Limited data availability is an additional hurdle to preparing grid impact studies and even more so for larger scale hosting-capacity analysis. SAGEN, in its new phase which is running from 2022 to 2024, aims to address this lack of data by including the development of asset registers in the extension of the Municipal Support Programme.

3.4 Integration Studies: How DREs fit into the broader bulk power-system

Integration studies are very effective tools to understand the impact of DRE deployment on the power-system, particularly for future scenarios with high levels of renewable generation. These studies can be co-ordinated by technical support providers and initiated by the ministry of energy, the utility, the regulator, or the system operator, and are shaped by the study objectives; no two integration studies use the exact same set of methods. Integration studies can help understand:

a) The future generation and transmission investments needed to accommodate the deployment of renewables and aggregate demand over time

b) The flexibility and reliability requirements and constraints as a result of increased levels of intermittent, non-dispatchable DRE resources

c) The electricity generation cost and net emission impacts from the changes in generation dispatch patterns

d) The impact of regulatory and policy frameworks on total costs.

Although there is no established set of rules as to which methods to use in an integration study, most integration studies include at least one of three analysis types with distinct analysis time-scales. **Load (or power)-flow studies** focus on the technical and reliability implications of adding high levels of renewables to the grid, often at very short timescales: These are engineering studies to understand how the addition of new elements to the grid may impact on steady-state voltage and stability in the grid. **Production cost studies** model the impact of renewables, including DREs, on the details of system operations by the hour, day, or period, often *over one year*. This allows for a more detailed understanding of how renewables affect the cost of operating the grid and where it runs into flexibility constraints, which may inform ancillary service or other regulatory policies. **Capacity expansion studies** are used to forecast optimal generation and transmission investments over *several decades*. In order to do so, they simulate least-cost investment decisions based on capital costs, operating costs, modelled generation profiles of renewable energy sources, including DREs, and the temporal variations in forecasted load. With more geographic granular renewable deployment and load data, capacity expansion studies can also simulate how much, and where, transmission is to be developed in the grid.

Stakeholder engagement and a transparent process is important at each stage of the integration study to ensure that all stakeholder groups have had a chance to engage with the policy-makers and share any ideas or concerns. Technical support providers can play the co-ordinator role for an integration study, facilitating the public consultation and dissemination process, and working with experts to conduct the analysis. Integration studies can have broad implications for the future of a country's electricity grid, as the focus goes far beyond DREs or renewables more generally, but they do allow a thorough understanding of how renewables fit within the longer-term electricity grid structure. Renewables have the greatest potential to be integrated into rapidly-growing markets, where capacity and generation is dynamic and renewables can fill capacity requirements without replacing existing generation. In markets with over-capacity, renewables are more likely to displace conventional fuel generation technologies, leading to concerns about the under-recovery of fixed generation costs for conventional generators. This could either leave the electric utilities, which have signed 'take-or-pay' contracts with independent power-producers, having to pay for fixed costs or, if the electric utilities own the generation, stranded assets. Integration studies can help inform how existing generation would be operated – and how their revenues would be affected – in a higher renewable energy scenario. These studies must consider both centralised and distributed renewable energy; countries with limited land area for centralised renewables can consider scenarios with high DRE levels.

4 Regulatory and Policy Support and Analyses

With the evolution of DRE markets and technologies, countries often consider new rules and regulations while balancing multiple (sometimes incongruous) policy objectives. Targeted regulatory support can provide options for countries that fit their DRE programmatic objectives, drawing on international experiences (from the African continent and beyond) to understand the benefits and challenges of various options. These policy options must also consider the stage of DRE development in the country, as described in Section 2 above. Relatively blunt policy instruments, such as full net metering, can be appropriate for early stage countries, limiting any potentially adverse technical and financial impacts due to limited DRE deployment. A more complex set of rules for installers, investors, electric utilities, and customers may be appropriate in countries that have more experience with DREs and where the potential technical and financial impacts of regulatory decisions are more significant, resulting from the higher installed capacity. Moving too quickly towards complex regulations can stunt the growth of the DRE market, whereas keeping relatively simple (and often generous) DRE compensation mechanisms too long can lead to technical and financial challenges. Hence, part of the support by technical assistance providers is to help inform policy-makers about the implications of DRE support policy decisions.

In this section, we introduce how technical support organisations can support regulatory frameworks which enable DREs by means of analysis and capacity-building. This includes support for energy ministries, other government agencies, electric utilities, and civil society, as well as the DRE industry. Similar to the technical support analyses described in Section 3, involving stakeholders through participatory processes ensures transparency and consensus-building – key for the development of sustainable DRE markets. Technical analyses (introduced in Section 3) and financial/economic analyses (to be discussed more in Section 5) both provide information as to which regulator and support policies are appropriate.

4.1 Matching DRE regulations to policy goals

DRE regulations, which define how DREs interface with the grid, and how DRE system-owners are compensated for the electricity generated by DRE, are designed to reflect the country's policy objectives. Historically, countries which have aggressive renewable targets have had policies that look to incentivise DRE development by means of generous compensation mechanisms and simplified interconnection procedures. Possibly the most notable example is Germany, which developed a set of regulations – including generous feed-in tariffs and simplified interconnection processes – in the 2000s which enabled it to quickly develop a DRE market (mostly solar photovoltaics), an active base of installers, and also to drive down the price of solar through learning and economies of scale [11]. However, other countries may not have DRE targets and are looking to interconnect DREs into the grid in a way that is least disruptive to the status-quo. When this is the case, DRE support policies would be designed to *enable,* but not necessarily *incentivise,* DRE installations. Clearly, support policies for this latter group of countries would differ from those looking to maximise DRE deployment, even at a net cost to the utility and ratepayers.

Box 6. TUNISIA CASE STUDY: Promoting Solar PV in the Agricultural Sector

Sector-specific analyses and support are prerequisites for fostering a robust DRE market and for sparking private sector DRE investments. In Tunisia, various GIZ projects have focused on the promotion of renewable energy in the agricultural and agrifood sector. In 2016, GIZ organised a multi-institutional working group in Tunisia with representatives from the agriculture and energy sectors: the Ministry of Agriculture, Water Resources and Fishing (MARHP), the Agency for the Promotion of Investments in Agriculture (APIA), the National Agency for Energy Management (ANME), the Tunisian Union of Agriculture and Fishing (UTAP) and the Tunisian Technical Centre for Agrifood (CTAA). Activities included technical and economic potential analyses, information campaigns and raising awareness in the sector, and technical advice and training.

GIZ's goal was to bundle efforts in the agricultural and energy sectors and to build a more coherent framework to allocate clear responsibilities between the involved agencies, as APIA and ANME both manage a subsidy fund for DRE deployment, for example. To this end, APIA and ANME signed a convention to further co-ordinate their respective funds – moreover, a guide has been published to inform APIA and ANME agents, as well as interested investors, about the procedures and legal framework of the subsidies.

Given the challenges Tunisian farmers face in accessing credit or other financing in the financial market, GIZ developed recommendations and an overview of available financing options. This led to a dialogue with banks and micro-credit institutions on PV-financing in the sector to discuss the challenges, as well as identify solutions that would trigger the development of targeted financing products. Although this activity involved different stakeholders, it has not led to the intended result; the COVID-19 crisis started shortly after the end of this activity, leading to access to all financing becoming even more difficult in Tunisia, and sector-specific finance products not being developed.

Further information can be found in the GIZ documents (published in French): Promotion du Photovoltaïque dans le secteur AGR/IAA en Tunisie - energypedia.

4.2 Promoting transparency and the democratisation of energy

Technical support providers can implement projects which suggest a suite of policy options that policy-makers and ministries of energy can consider to best match their policy goals. This includes presenting case studies from other countries (of similar or different economic contexts) to those responsible for creating DRE regulatory rules and to assist them in selecting policies to be refined to best fit the local economic and political context. Community leadership and stakeholder engagement are key to ensuring that these rules are accepted and understood by all, and to promote transparency and the democratisation of electricity regulatory frameworks. International organisations can facilitate engagement by providing a neutral environment for exchanging ideas and input constructively and productively.

There are two distinct activities which technical support providers can lead. The first is to help establish a set of rules of engagement that empower communities and stakeholder groups as DRE policies and rules are developed. Again, there are many resources that delve into stakeholder engagement and leadership as the basis for the democratisation of energy (e.g. [12], [13], [14]). The second is to act as the facilitator in the selected process and provide local and international expertise, as well as logistical support – including inviting diverse stakeholder representatives, which may require travel and accommodation, meeting co-ordination, and conference-room rentals.

4.3 Data for improved DRE regulatory support

Tracking DRE deployment is essential to understand progress towards a country's (or region's) DRE goals and to accurately assess the financial and technical impact of existing DRE systems. It enables data-driven decision-making informed by rigorous analysis, whilst also promoting transparency in DRE regulatory frameworks. There is significant value in supporting data-collection systems and processes being put in place by regulatory bodies, and this requires utilities or DRE installers to report information on all the installed systems. This data can include date of installation, exact location (e.g. address where the DRE is located), DRE technology type (e.g. rooftop solar, battery storage, distributed wind), system characteristics (e.g. system-size, manufacturer/model, installed price), customer characteristics (e.g. tariff class, monthly or hourly consumption and PV generation), installer name, incentive types and levels (when applicable). In some jurisdictions, this data-sharing is done online and is required for interconnection approval. Technical support providers can assist in determining what data would be most useful in the local context, the implementation of the data collection platform, including the development or purchase of appropriate secure software, and how to design a data collection process that maximises the chances of quality data collection.

4.4 Equity in DRE deployment

In most contexts, maximising access to DREs and improving equity in deployment and benefits from DREs is a policy goal, ensuring that the deployment of DRE benefits all and does not result in increased social and energy inequity. In the residential sector, historically, only higher-income households have been able to access the cash or financing to be able to benefit from the purchase, or lease, of a rooftop solar system. Low-income households are almost completely excluded from on-grid solar unless incentives are provided to drastically reduce the upfront costs. In some contexts, 'green enclaves' are created where high-income households and commercial entities have access to higher quality power through DREs, which further encourages unequal societies [15]. Decreasing sales for utilities from rooftop solar can lead to higher retail tariffs for electricity, leading to potential cross-subsidies from non-solar adopters to solar adopters, creating further inequities. This is the topic of debate in many jurisdictions, including in the US where solar deployment is approaching, or has surpassed, 10% in a few states (e.g. California, Massachusetts, Nevada, Hawaii). In fact, increasing DRE deployment alone is no longer the goal in a number of countries, *equitable* DRE deployment is the goal in which the benefits of DRE are to be shared amongst all. There are a number of regulatory solutions to increase access to DREs and reduce cost-shifts that countries can adopt, again drawing on international experiences, but customising for the respective local country context. Technical support organisations can provide support to energy ministries and government entities by assisting in the design of DRE programmes that do not exacerbate social and economic inequality, at the very minimum.

Several policy initiatives can be designed to increase access to DREs, mostly by removing obstacles to the adoption of DREs by lower-income households. These policies are:

a) **Targeted direct incentives to reduce (or eliminate) upfront costs of DREs.** When income verification is feasible, then this is the most accurate method to determine eligibility for low-income programmes. However, given that most low-income households may not file tax returns in some countries, other eligibility criteria may be more appropriate, such as subscribing to 'lifeline' electricity tariffs, indicating low electricity usage. These incentives can be funded by redirecting existing electricity subsidies, as some customer classes have reduced tariff levels, often from existing state subsidies or cross-subsidies from other customer classes.
b) **Shared DREs (or virtual net metering)** to allow those without access to rooftop space, who do not own their home, or are small electricity consumers to benefit from DREs – these are also known as 'community DREs'; shared DRE is a policy mechanism to allow a single DRE installation to be shared amongst a number of households. There are a variety of models with differing rules for participation, payments, and bill credits, which can be adapted to the local context (e.g. [16]). This allows those who do not own their home and those without adequate space (often characteristics of lower-income households) to access the economic benefits of DREs. Policies that enable shared DREs can either be open to all customers, or targeted to certain customer classes.
c) **Financing**. Many low-income households do not have access to loans from financial institutions to purchase a DRE system. States can facilitate this by creating loan programmes which target lower-income customers with on-bill recovery, such that loans are repaid as part of the customer's electricity bill. States or international funding organisations can also provide loan guarantees to private banks to reduce the risks in case of default, and encourage DRE loans.
d) **Business models that decrease upfront costs**. Policies can enable third-party ownership of DREs, where a DRE is installed on a host customer's property, but owned by a third-party, with a financial agreement for the host to pay for the electricity generated by the system. This type of arrangement may require changing existing rules and regulations, as regulated electric utilities may be the only entities permitted to sell electricity to customers, thus this type of arrangement is sometimes met with resistance from electric utilities, which may see third-party ownership of DREs as a form of direct competition. In some circumstances, these concerns can be assuaged by allowing utilities to also own DREs to install on customers' properties. Utility ownership of DREs, which requires a separate set of rules and regulations to ensure competitive DRE markets, can provide benefits to utilities and ratepayers more generally, too [17].
e) **DRE pilot projects and information campaigns**. DRE adoptions among lower-income households may be low in part due to the lack of awareness about the technologies and how they can help reduce electricity bills. Pilot projects which install DRE systems in lower-income communities may make these technologies more visible and can help drive more demand. Information campaigns – the creation of pamphlets, public service announcements, community meetings, community DRE 'ambassadors' – can be helpful in encouraging familiarity with the technologies.

4.5 End-of-life recycling

Components of DRE technologies lifespans are limited and eventually end up in the landfill unless proper mechanisms are established to ensure they can be diverted from the waste-stream and enter recycling programmes. Depending on the specific DRE technology, DRE components and balance of system can contain metals that are toxic to human health and the environment if disposed of improperly. For example, most solar panels manufactured today contain cadmium and lead, and batteries used for back-up often contain cobalt, copper, nickel, amongst other elements, all deemed to be hazardous to humans and ecosystems [18]. Recycling DRE components can be expensive and requires the development of supply chains to collect and transport these to recycling facilities that can be outside the country. Although there are valuable elements which can be recovered through recycling, the upfront investments in the facilities and energy usage can be prohibitively high. Unless the economics of DRE component recycling change over time, end-of-life recycling will likely not occur organically without financial incentives or directives, both of which can be set-up through policies and regulatory mechanisms. Support organisations can also assist in the development of these policies. A first step is ensuring that policy-makers have the latest information on the risks of inaction to human health and the environment by inviting national and international experts in the field to discuss the potential end-of-life impact and options for the recycling, or proper disposal, of the DRE technologies being supported in the target country. End-of-life recycling may not be a priority if policy-makers are not aware of the potential issues relating to the disposal of DRE components. If there is interest, then support can begin with an introduction of international best practices. Providing local decision-makers with examples of successful programmes in other countries can provide the necessary motivation and conviction to create such a programme that suits the national context (e.g. [19]): This includes the introduction of international industry standards (e.g. [20], [21]), the involvement of manufacturers, and international collaboration opportunities. [22]

4.6 Interconnection and permit procedures

A major obstacle to DRE deployment can be cumbersome and inefficient interconnection procedures, which can slow down the approval process for applications and create uncertainty for DRE developers, installers, and potential customers. Providing support on streamlined interconnection procedures can have a significant impact on deployment speed, market confidence, and programme costs. Again, support should draw on international best practices and experiences, when appropriate. DRE interconnection procedures need to be easy to understand, quick to implement, and minimise the time demands for installers, utilities, and customers (see [23] for an example of best practices).

Developing proper permit procedures for the local or national government and the electric utility ensures that the system meets minimum safety and quality standards and that it does not adversely affect the electric grid. If this step is too cumbersome and complex, this can lead to significant delays and additional costs for installers and end-use-customers alike, ultimately adversely impacting on the DRE market. However, the opposite can also lead to a similar outcome. If the permits are too easy to acquire (or if there is no permit system at all), then the DREs can get to be seen as unreliable and unsafe technologies, negatively affecting their reputation and slowing the adoption of these technologies. [24]

Box 7. SOUTH AFRICA CASE STUDY: Interconnection and Permit Procedures – Municipal SSEG Support Programme

As described in Box 2, the absence of national guidance on DRE application and interconnection approval processes means that the responsibility for developing the relevant processes and building the required capacity lies with the municipalities.

To assist in this, the Municipal SSEG Support Programme was developed to provide municipalities with templates, standardised processes, and training addressing all the relevant aspects of DRE integration. The first step in the programme was to develop the 'Resource Pack'. The resource pack is a compilation of guidelines, templates, and processes covering the relevant aspects of SSEG integration, and is approved by the Association of Municipal Electricity Utilities of Southern Africa. A detailed breakdown of the different documents can be found at https://www.sseg.org.za/ameu-resource-pack/.

To assist municipalities in implementing the resource pack, a five-day training programme was developed and executed twice-a-year. Moreover, a dedicated website was developed and a helpdesk provides ongoing hands-on support to municipal partners on all DRE-related topics. The programme also developed specialised training on specific topics (e.g. SSEG tariffs, bi-directional metering). To avoid interruptions during the COVID19 pandemic, the programme developed an online training platform and offered recorded online training sessions, with Q&A sections and practical exercises for live participants. The training platform and recorded training sessions are freely available.

Participation in the Municipal SSEG Support Programme was widespread, including 77 out of 165 municipal distributors, as of September 2022 (SAGEN: Embedded Generation in Distribution Networks - YouTube). However, the key challenge going forward will be to ensure that the interventions are sustainable. The objective was to create a critical mass of staff members well-versed in specific topics around SSEG who would then form additional capacity in their respective municipalities. However, a recent survey has shown that this goal has only been achieved in some municipalities. The challenge is exacerbated by high staff turnover.

By implementing the programme with local partners receiving funding through grant agreements, the aim is to have the support continue beyond GIZ's direct involvement. Furthermore, GIZ plans to offer courses that train individuals or organisations which could then themselves train others using the material developed, in order for other public and private training providers to offer the courses either on a commercial basis, or funded by other donor organisations.

Box 8. TUNISIA CASE STUDY: Promoting DRE in the Private Sector and Training Qualified Personnel

In Tunisia, private power-producers can operate within three regimes: self-generation, authorisations, and concessions. However, this being a rather young sector with the law relating to the production of electricity from renewable energy first entering into force in 2015, there has not been a comprehensive resource describing the different regimes and their respective procedures, thereby promoting possibilities for private actors to invest in DRE in Tunisia. In 2019, a guide for DRE deployment was developed by two GIZ projects in collaboration with the Ministry of Industry, Mining and Energy (MIME) and the national Agency for Energy Management (ANME).

The development of renewable energy holds great potential for employment in Tunisia, and would help the country to ease its unemployment problem, which has risen to 30% for young graduates of higher education. Since 2015, GIZ has supported the Tunisian partners in the development of national qualification structures to strengthen the technical skills required in the solar-energy sector. In close collaboration with 19 'trainers of trainers' representing nine public and private partner institutions, a continuing education programme in photovoltaics (PV) has been developed and implemented. Following a participatory approach, GIZ first strengthened inter-sectoral co-operation and intensified the collaboration between vocational training centres and PV installation companies, in order to help them implement vocational training adapted to the market needs. It has also supported the development of a training programme entitled 'Installer-Maintainer of Grid-Connected PV Systems' which has now been institutionalised in professional training centres. This training is a requirement for PV installers to receive the official accreditation by ANME, and thus helps to standardise and enhance the quality, and therefore longevity, of PV systems. Furthermore, it provides qualified employment.

5 Financial and Economic Support and Analyses

This final section focuses on the economic and financial analyses to support informed, evidence-based DRE policy-making. Although governments may be motivated by environmental and carbon emission reduction related to DRE deployment, industrialising countries are often under economic pressures to ensure that DRE programmes provide a net financial benefit to various stakeholders, including residential, commercial, and industrial electricity ratepayers, electric utilities, and the government. Financial flows resulting from DRE generation can be difficult to summarise as they accrue to different actors, and costs for some stakeholders can be benefits to others. They can also be difficult to quantify as the data is not always available to model or calculate impacts. However, developing methods and analyses that are based on local policies, transparent and reproducible, is key to developing trusting relationships amongst DRE stakeholders and ensuring acceptable and equitable economic effects for all.

Financial and economic analyses are often classified into three categories:

- **Customer economics and DRE deployment analysis.** Understanding how attractive a DRE investment is to the end-use customer, given current or proposed DRE support policies, is a threshold question; if DRE policies do not make DRE investments attractive to customers, then only customers motivated by factors other than financial incentives will adopt these technologies. Customers driven only by the non-economic benefits (e.g. environmental) tend to be relatively few, and the DRE market is unlikely to grow under conditions where the economics are not favourable to investment.[3] Using the results of customer economic analyses and the economic performance expectations of various customer groups, customer adoption can be forecast using the probabilistic economic DRE potential model[4].
- **DRE utility tariff and revenue impact analysis.** A common concern regarding DRE deployment, expressed by electric utilities and other stakeholder groups, is the potentially negative impact of DREs on utility finances. In particular, if electricity customers are able to produce their own electricity and reduce their electricity bills, then utility revenues fall. However, the overall financial impact from DRE deployment also includes the benefit from DREs to the utility: the avoided costs. If DRE leads to avoided costs that are similar in magnitude to the reduced revenues, then the net utility financial impact can be minimal. Even when avoided costs are lower than the reduced revenues, the net financial impact may not be significant in magnitude if deployment levels are low. In any case, to evaluate a current or proposed DRE policy, the ministry, regulator, and utility needs to quantify what those net financial impacts are for various stakeholders, chiefly the electric utilities and non-DRE adopting electric ratepayers. Methods to do so have been described in [25].
- **Macro-economic, subsidy, and job impact analysis**. The central government may want to understand other economic effects from DRE deployment. For example, the development of the DRE market could lead to local job creation through the network of local installers and companies providing maintenance. Jobs studies can help understand how many, and the types of, jobs which could be created (e.g. [26]). Subsidy and tax revenue analyses can quantify how DRE affects government subsidy and tax revenue levels, in cases where electricity is subsidised by the state and DREs lead to fewer electricity sales or changes in tax revenues (e.g. decreases in electricity tax revenues, increases in DRE equipment tax revenues).

  Support is both in the form of sharing analysis results with DRE stakeholders, as well as capacity-building.

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[3] For governments who are not looking to develop a local DRE market, but just looking to enable their interconnection, this may be an acceptable result.

[4] The U.S. National Renewable Energy Laboratory has developed an open-source DRE adoption model that can be adapted to specific country contexts: the DGEN model.

- **Co-deployment of DREs and other distributed energy technologies** (e.g. storage, energy efficiency, demand response). As new regulations allow customers to become active participants of the electric grid, by means of grid-interactive technologies, DRE will increasingly be co-deployed with other distributed energy resources (including storage and energy efficiency) to maximise customer electricity bill savings. Financial analysis of co-deployed technologies can provide information on how electric utilities can benefit from co-deployed technologies, and what tariff designs can best align customer bill savings and utility value.

Box 9. TUNISIA CASE STUDY: The Costs and Benefits of Distributed Solar

Policy analysis based on transparent methods and assumptions provides decision-makers with a more holistic understanding of the impacts of DRE deployment, including the financial costs of DRE deployment, as well as the potential cost savings. This can also give them the confidence needed to move forward with DRE support policies and setting more ambitious DRE targets, when advantageous to do so.

Tunisia has set a target for renewable energy deployment, 30% of its electricity generation is to be from renewable sources by 2030, as part of its official targets, with just under 20% of that coming from rooftop solar. Financial analyses can help the government of Tunisia understand the *costs* of rooftop solar, given current subsidies and compensation mechanisms, and the associated *cost savings*, mostly in the form of avoided costs for the utility.

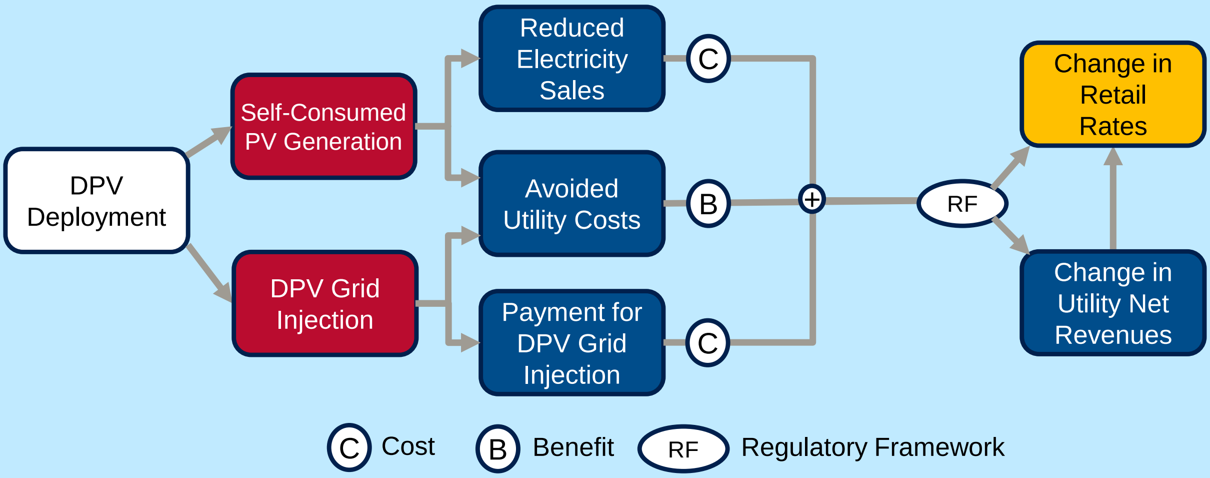

FIGURE 3: Framework to quantify costs and benefits of distributed solar deployment [27]

As part of the 'Solar Market Reinforcement' project, GIZ organised a working group led by an international expert and composed of members of the electric utility (STEG), the Tunisian Ministry of Industry, Mines, and Energy, the National Agency for Energy Management (ANME), the Ministry of Finance, and other stakeholders, to develop a framework and conduct a first-pass analysis of the costs and benefits of distributed solar to the government and STEG.

GIZ's principal goal for this analysis was to build capacity within each of the stakeholder organisations to understand the elements of the analysis and be able to either conduct a similar analysis, oversee such an analysis to be executed by a third-party, or review the output. The working group was responsible for collecting data and conducting parts of the analysis, and for developing a number of scenarios to investigate, including different levels of DRE deployment and high/low oil prices, for example. Although the methods for the calculation of avoided costs were simplified, based on generator characteristics for Tunisia and least-cost dispatching approximations, the analysis provided the working group members with an holistic understanding of how distributed solar impacts on revenue collection and operating costs for the utility, as well as what assumptions the analysis are most sensitive to (namely, in the case of Tunisia, the retail rate escalation and the price of natural gas which is pegged to that of oil).

Box 10. TUNISIA CASE STUDY: Customer Economics of Distributed Solar – the PROFITPV Tools

DRE customer education – understanding the value proposition from DREs – is key to developing a healthy DRE market. Potential customers need a basic level of understanding of the (electricity) bill savings to be made from DRE in order to decide to invest in a system; complicated compensation mechanisms and retail rate designs, as well as a lack of available relevant data, can lead to significant uncertainties in the financial expectations for customers, a major obstacle in DRE deployment. DRE installers often fill this void by providing their own calculations, although these are often unclear and may make optimistic and unrealistic assumptions.

In the last five years, GIZ has developed a suite of tools that quantify the customer economics of solar in Tunisia: PROFITPV. These tools have been developed using standard financial principles based on cash-flow analyses and are customised to the Tunisian context, including the details of the compensation mechanisms, retail rate structures, bill calculations, PV generation estimates, and customer load profiles. These five tools are freely available and only require Excel to run, making their methods transparent and their usage widely accessible. In the tool, there is an explanation of the PV compensation mechanism with simple examples and graphics, so that users start by understanding how solar reduces their electricity bills. Users enter basic information about the PV system, including costs, and PV system characteristics (size and location). More advanced inputs – related to financing or rate escalation assumptions, for example – are filled-in with default values, although users can choose to modify these. The tool then provides a suite of indicators, including basic profitability metrics (e.g. payback time, rates of return) and other outputs (e.g. electricity bill estimates with and without solar, annual solar generation, average value per kWh of electricity generated), as well as a number of graphics that help the user to understand their annual cash flow and bill savings. A number of sensitivity analyses helps the user understand how the results change as particular assumptions change in value. Finally, the user can print a summary page with the basic sets of inputs and outputs. All the calculations are included in separate tabs in the excel file for transparency, although the user does not need to review or understand these in order to use the tool. GIZ has also developed a set of training videos which teach users how to use the tools, freely available on YouTube.

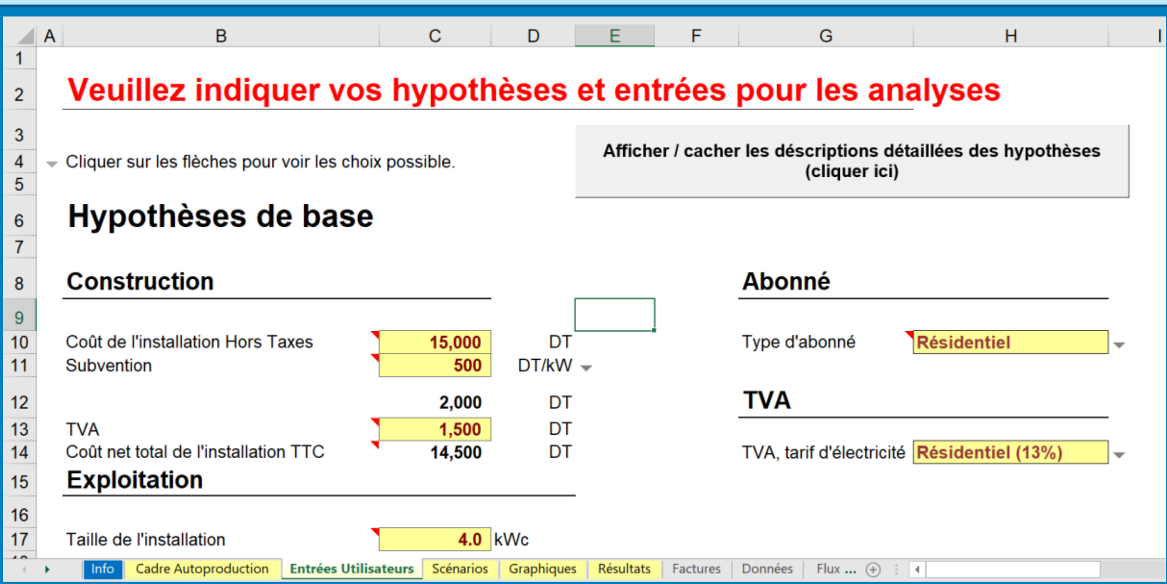

FIGURE 4: Screenshot of the PROFITPV tool for low-voltage solar in Tunisia

The PROFITPV tools were reviewed in detail and validated by the electric utility (STEG) as well as by members of the Ministry of Industry, Mines, and Energy, the National Agency for Energy Management, and other stakeholders. The tools are now widely used by the Ministry to review interconnection applications, and by solar installers to create customised reports for potential customers, as well as by potential customers to understand how solar leads to financial savings.

Box 11. SOUTH AFRICA CASE STUDY: DRE Revenue Impact Analysis and Tariff Development

One of the goals of the Municipal SSEG Support Programme is to provide municipal distributors with tools which help to promote an understanding of the potential financial impacts of DRE deployment. First, SAGEN funded the development of an excel-based municipal revenue impact tool that quantifies: (1) the financial impact of the increased deployment of solar PV on municipal revenues, and (2) the customer economics of solar PV. The tool is complemented by documents and presentations, as well as additional software tools, and the package can be downloaded for free at the SSEG Municipal Resource Portal. Applying the tool in several municipalities showed that, with an unbundled tariff structure, it is possible for a municipality not to incur any losses due to DRE deployment, even when the investment remains profitable for the DRE customer. The five-day general SSEG training for municipalities was modified to include SSEG tariff development. In addition, the programme also developed dedicated training to provide municipalities with a more detailed understanding of SSEG tariffs. As part of this in-depth training, participants have a chance to develop an SSEG tariff for their municipality using the materials and methods learned during the course of the training.

Although many of the municipalities which participated in these training sessions had intended to implement the SSEG tariffs developed during the training, many face challenges in adopting the tariffs. Existing residential and small commercial tariffs are fully-bundled and include only a volumetric energy charge (per kWh). However, a fully-bundled tariff that only consists of a volumetric energy charge leads to higher revenue losses for the electricity distributor. Consequently, the tariffs for DRE customers developed during the training sessions were unbundled into a (lower, ideally time-variant) volumetric charge and a fixed, monthly charge.

The introduction of unbundled tariffs, however, often faced opposition not only from municipal management and the municipal council as this required a revamping of metering, billing and accounting, but also from electricity customers who perceived the unbundling of tariffs as a way to disincentivise SSEG installations. In order to address the latter challenge, communication support activities have recently been added to the programme. This enables municipalities to discuss the new tariffs with stakeholders and explain the reasoning behind their design, showing how they were designed to be fair and transparent.

Another challenge that was encountered as part of the tariff design work was the lack of recent cost-of-supply studies. Any new tariff should be informed by a cost-of-supply study to show that it is reasonable and fair to all. However, many South African municipalities have not conducted such studies for several years and, in most cases, do not have the required, up-to-date data on their assets to be able to conduct such analyses. As a result, SAGEN added these two topics to the programme’s training, offering practical support including a simplified cost-of-supply tool and, going forward, assisting in the development/improvement of asset registers (see also Box 5).

6 Conclusions

This Technical Assistance Manual summarises a number of potential support activities for practitioners looking to enable and develop distributed renewable energy in Africa (and beyond) through rigorous, participative, and transparent methods. These activities can be designed to support governments in setting-up appropriate DRE policies and targets, to assist electric utilities in the integration of DREs on their grid while maximising benefits and minimising any negative impacts (financial and technical), and to help potential customers and ratepayers understand the customer economics of DREs, as well as to generally build capacity and encourage evidence-based decision-making and opinions for all stakeholders. After introducing the three stages of DRE market development: early, mid, and mature, the manual outlines technical, regulatory/policy, and financial/economic support and analysis. Through nine case studies based on GIZ activities in Tunisia and South Africa, this manual provides examples of potential interventions, including methods used and challenges faced.

As countries develop their regulatory frameworks, utilities adapt their procedures and planning activities, the private sector innovates, and customers adopt DREs, they have the potential to dramatically transform the electric grid in African countries. Setting-up the appropriate DRE policies and building capacity amongst all the stakeholder groups will accelerate this process and ensure that DREs benefit everyone, providing help on the arduous road of development.

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