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How rooftop PV can enhance energy security for households across SADC

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Abstract:

Electricity security in SADC is a concern, with less than one third of the total SADC population having access to electricity. The region enjoys abundant sunshine which can be used to ameliorate the situation. This paper examines the use of Small-scale Embedded Generation (SSEG) in the form of Rooftop Solar Photovoltaic installations as a means to enhance energy security in the region. It firstly looks at the relationship between electricity and development, which makes clear the benefits of extending access to electricity. It then examines the global development of SSEG, starting with alternative policy approaches available to governments. Global solar PV capacity and selected country experiences are explored, with a focus on leading countries. A case study of South Africa is then explored in some depth. How rooftop PV can assist in solving the energy crisis in SADC is examined by looking at solar resources in SADC member states and the impact of SSEG on energy security. Lastly the paper examines the current policy status in each SADC state with respect to SSEG in particular and renewable energy in general, and some best practices from the international and SADC experiences are outlined.

JEL classifications:

Small-scale Embedded Generation (SSEG); Rooftop solar Photovoltaic (PV); SADC; Renewable Energy Policies

Contents

1. INTRODUCTION

Less than one third of the SADC region's population has access to energy, and innovative solutions are required to address the energy crisis in this region. This paper explores how solar Photovoltaic (PV) rooftop systems[1] can assist households and businesses across the SADC region in enhancing energy security. Energy security can be defined as "the uninterrupted availability of energy sources at an affordable price" (International Energy Agency [IEA] 2017). Energy security is a pre-requisite for economic development and thus a focus for developing countries around the world.

Green energy using low-carbon energy solutions has long been acknowledged as a solution to energy poverty and climate change internationally (UNEP 2011). Renewable energy technologies can assist countries in increasing access to electricity as well as reducing price volatility; providing secure, reliable and affordable electricity; and contributing towards social and economic development.

There are many renewable energy sources[2] – solar, wind, marine, hydro, geothermal and biomass – and renewable energy technologies have become more attractive options across the world for a number of reasons. Renewable energy never runs out, is environmentally friendly in terms of emissions, is available almost everywhere on earth unlike fossil fuels, is easily deployed and in recent years prices have fallen dramatically. In addition, renewable energy technologies have advanced which have made them more efficient and reliable.

This paper focusses on Small-scale Embedded Generation (SSEG) and rooftop solar PV in particular, although there are many other options for using renewable energy to address the electricity crisis. Embedded generation (also known as distributed generation or distributed energy) refers to power generation at the point of consumption. SSEG pertains to power generation under 1MW (1000 kW), which is located on residential, commercial or industrial sites where the electricity generated is also consumed. SSEG is in contrast to large-scale generation units that generate large amounts of power, typically in the multi-megawatt range. The majority of electricity generated should be consumed directly on site, however when production exceeds consumption electricity will be exported onto the grid.

The remainder of the paper is structured as follows:

- The paper firstly examines access to electricity across the SADC region and highlights the importance of access for economic growth. The relationship between access to electricity and poverty is also explored;
- Next the paper looks at the development of rooftop PV globally. This involves examining alternative policy approaches available to governments, after which global solar PV capacity is examined and then a number of country experiences, including South Africa, are outlined;

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[1] Rooftop solar PV systems refer to solar PV systems that are installed on rooftops and elevated areas on consumer premises. They can either be attached to the building or integrated into the building.
[2] Renewable energy includes solar (PV and CSP), wind (off-shore and on-shore), marine (wave, tidal, OTEC), hydro (storage dam, pumped storage, run of river), geothermal, biomass (biogas, dung, ethanol, gasifier, crop residue, firewood). Note that OTEC is ocean thermal energy conversion. (Ramagoma & Adendorff 2016).

- The paper then looks at how SSEG can improve energy security in SADC by examining the solar resources in the region and looking at the impact of SSEG on the elements of energy security;
- Finally, regulatory and policy regimes across the region are explored before best practice is outlined.

2. ELECTRICITY AND DEVELOPMENT

Electricity is an important prerequisite in any development plan as it underpins economic growth. Countries with low levels of GDP per capita and high levels of poverty tend to be those that lack access to reliable and affordable electricity services (Karekezi et al. 2012: 160; Castellano et al. 2015). This is most pronounced in Africa and South Asia, where the number of people who lack access to reliable electricity supply are the greatest (IEA 2016). Currently, shortage of reliable electricity supply and lack of infrastructure to generate electricity hinders economic development within SADC. As a result, most SADC member states experience regular electricity crises and outages.

2.1. ELECTRICITY IN SADC

From an electricity-access perspective, the situation within SADC is dire. In 2014, around 67% of the entire SADC population did not have access to electricity (IEA 2016). The table below shows the proportion of the population without access to electricity and the average number of outages experienced per month. The SADC countries are not homogenous in terms of access and outages, with Seychelles and Mauritius enjoying access for nearly all its citizens, whilst Malawi, Madagascar, Lesotho, the DRC and Angola all have over 80% of their populations without access to electricity. Note that when we refer to the energy crisis in SADC in this paper, we refer to the aggregate situation and not the situation in each individual country.

Table 1: Access to electricity across SADC

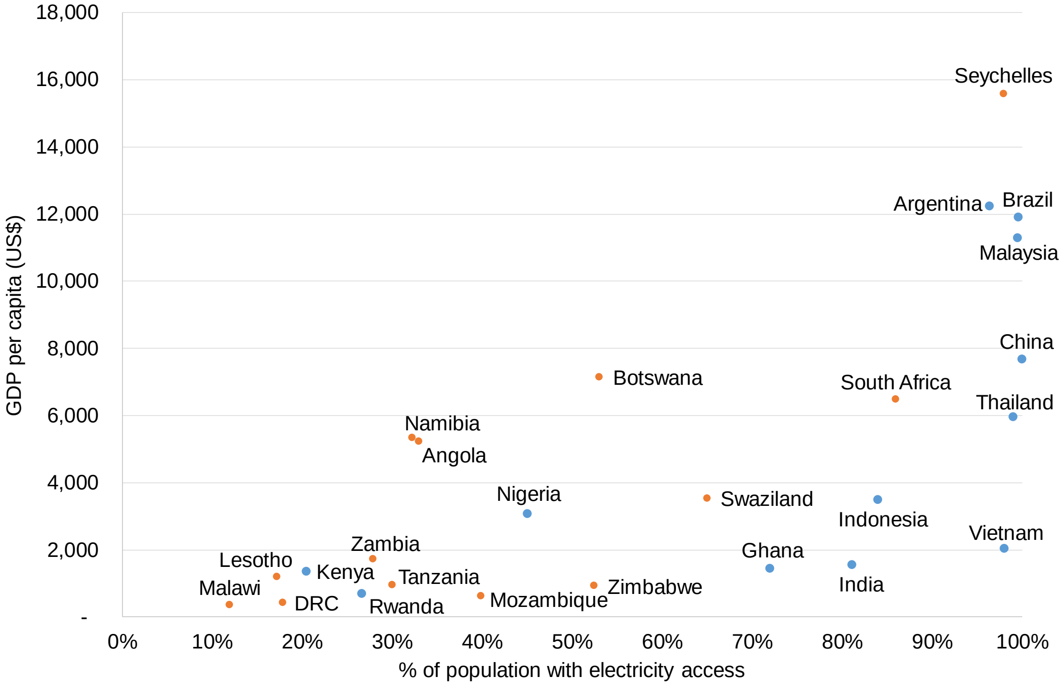
	Total population (millions)	Population without access to electricity	Proportion	Average number of outages per month
Malawi	15.8	14.7	93%	no data
Madagascar	22.4	20.5	92%	6.7
Lesotho	1.9	1.7	91%	4.1
DRC	69.8	61.5	88%	12.3
Angola	19.8	16.2	82%	4.7
Tanzania	47.9	36.3	76%	8.9
Zambia	15	11.3	75%	5.2
Namibia	2.2	1.6	73%	0.6
Mozambique	25	16.4	65%	1.6
Zimbabwe	13.4	7.2	54%	6.7
Botswana	2.2	1	48%	4.1
Swaziland	1.1	0.4	41%	1.8
South Africa	54	7.6	14%	0.9
Seychelles	0.1	0	2%	no data
Mauritius	1.3	0	0%	1.2
Total SADC	292	196.6	67%	

Sources: Total population from SADC Statistics Yearbook 2014; Population without access to electricity from the International Energy Agency (IEA) Electricity access database; Average number of outages per month from World Development Indicators database.

2.2. RELATIONSHIP BETWEEN ELECTRIFICATION AND ECONOMIC GROWTH

There is a strong link between electrification and growth. As illustrated in the figure below, countries with electrification rates of less than 80% of the population have consistently lower levels of GDP per capita. Countries such as Malawi, Lesotho, the DRC, Zambia and Tanzania, with electrification rates below 50%, have lower levels of GDP per capita; while countries with electrification rates above 80%, such as South Africa and Seychelles, have higher levels of GDP per capita.

Figure 1: Percentage of population with electricity access versus GDP per capita (US$)



Source: World Bank data (2016) and IEA data (2016); Authors' calculations.

Similarly, there is a clear link between quality of electricity supply and GDP (Castellano et al. 2015: 8). This emphasises the critical role of both availability and reliability of electricity supply in promoting development.

Lack of reliable electricity supply has a significant impact on productive employment, income generation and job security. It is estimated that in Sub-Saharan Africa (SSA) businesses lose value worth 8.3% of their annual sales due to electrical outages (World Bank 2016).

At the macroeconomic level, lack of reliable electricity supply is estimated to have a significant impact on economic growth and productivity. For example a study by Vivien and Briceno-Garmendia (2010) found that the proportion of GDP lost due to unreliable electricity supply in Malawi, South Africa, Tanzania and Madagascar was approximately 6.7%, 5.8%, 4.5% and 1.2% respectively.

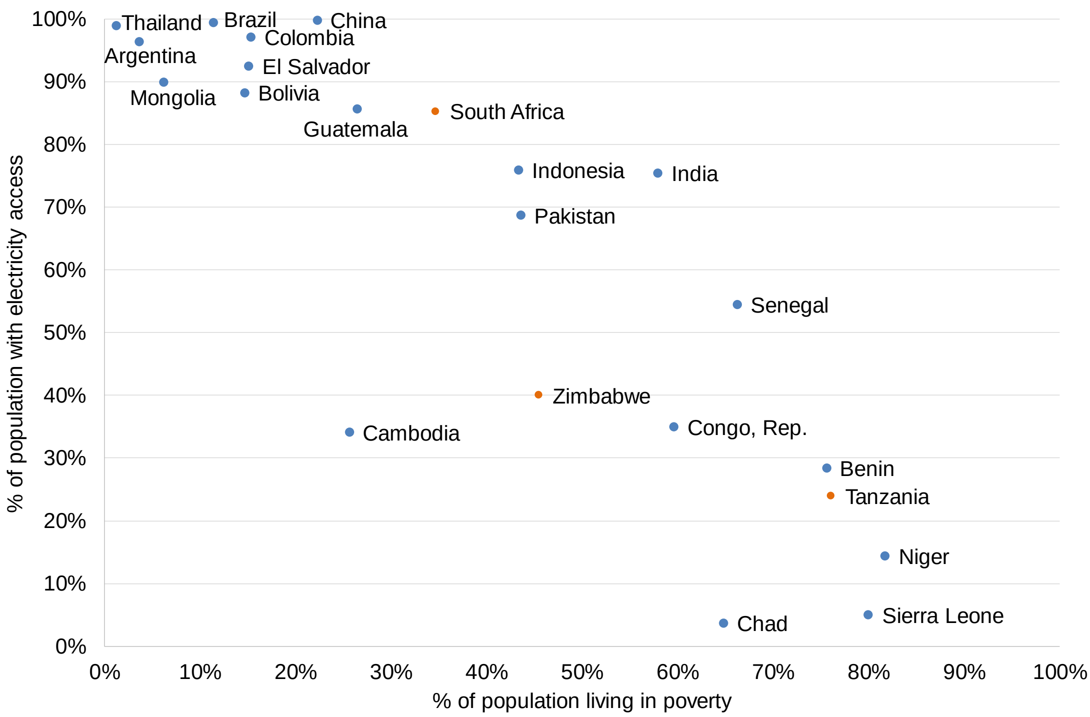
Although the lack of access to reliable electricity supply impedes growth, it does not completely restrain it. The growth, however, comes at a significant cost. In a number of SSA countries, many individual businesses in the industrial, commercial and residential sectors own generators to make up for the lack of access to and supply of electricity. For example, 42% of businesses in Tanzania own generators (Castellano et al. 2015: 8). On average, power from electric generators is four times the price of grid power (Castellano et al. 2015: 8). For many businesses, however, grid power is intermittent and in some cases entirely unavailable, making the additional price for generator power a necessary and standard cost of doing business.

The extensive use of generators in SSA countries distorts the cost of doing business. As a result, businesses that operate in the region have considerably higher relative electricity expenses than their counterparts in other regions. In addition, many enterprises that do business in other parts of the world never take off in SSA, because local electricity costs make them uncompetitive (Castellano et al. 2015: 9).

2.3. RELATIONSHIP BETWEEN ELECTRIFICATION AND POVERTY

As previously stated, countries with high levels of poverty tend to be those that lack access to electricity, this is illustrated in the figure below.

Figure 2: Percentage of population living in poverty[3] versus percentage of population with electricity access



Source: World Bank Poverty and Equity Database (2016) and IEA data (2016); Authors' calculations.

The correlation between electricity access and poverty is supported by a number of World Bank studies. A study by Barnes et al. (2010) found that increased access to electricity contributes to monetary gains among the poor and leads to better quality of life such as an improved diet and amount of food intake, and the ability to afford better health and educational facilities.

Electricity can contribute towards enhancing food security among the poor through technologies that can be used for irrigation and water pumping. Some irrigation and water pumping technologies have potential of ensuring food supply throughout the year and also producing additional income for households (Karekezi *et al.* 2005).

[3] Poverty is defined using the World Bank's Poverty headcount ratio, which is the percentage of the population living on less than $3.10 a day at 2011 international prices.

Electricity can also provide a reliable and sustainable source of energy for household cooking. In many poor countries, biomass, used mainly for cooking, accounts for over 90% of household energy use. While traditional fuels such as wood, agricultural residues, or manure can be collected locally, considerable time and effort may be spent collecting these fuels. As traditional fuels become scarcer increasing amounts of unpaid time is spent collecting fuel, leaving less time for income-generating activities (Karekezi *et al.* 2005: 166). Enhancing access to modern forms of household energy is important because of its potential for increasing household income levels.

Electricity can facilitate access to educational media in schools and in households. It provides the opportunity to use sophisticated equipment for teaching, allowing access to specialised teaching materials and courses, and can increase use of distance-learning modules (Mapako 2010). In addition, it also provides several health benefits including greater use of more advanced medical equipment, the provision of medical services at night and facilitating vaccination and medicine storage.

It is important to emphasise that access to electricity constitutes only part of the desired policy objective of reducing poverty. It is necessary for creating the conditions for economic growth and improving social equality, but electricity, on its own, is not sufficient for households to move out of poverty. It can help drive economic growth by improving productivity and also by increasing the range of employment options in rural and urban areas, through the expansion in the range of services for manufacturing, mechanical power, and illumination it provides. Prioritising access to electricity for commercial activities could therefore increase employment opportunities that can contribute to income generation among the poor.

3. DEVELOPMENT OF ROOFTOP PV GLOBALLY

Electricity systems have been characterised by vertically integrated utilities with large scale and dispatchable generators. Such systems benefit from economies of scale, holistic system planning, and investment certainty, but suffer from monopolistic supply structures, with reduced levels of innovation, lower levels of service quality and a lack of price and customer competition.

The role of electricity systems, however, has evolved with the splitting up of integrated utilities into separate network businesses, and enhancing private and competitive operations through the integration of large shares of variable renewable generators such as rooftop PV systems at the distribution level. With the increasing shares of variable renewables at the distribution level, electricity will start to flow back into the transmission system. The aggregation of small-scale market participants can be relevant to form a reliable supply of electricity. A higher level of integration between distribution and transmission systems can potentially maintain reliability, reduce generation costs on the transmission level, and reduce network losses (Volk, 2013: 85).

Traditional energy systems have been described as “linear and static” by the Africa Progress Panel (APP) (2017: 18), and the key is to transform them into systems that are resilient and diverse, with multiple options for electricity access. These multiple options involve extending the grid within a country and across national borders and diversifying the energy mix; the installation of mini-grids[4]; and, the installation of solar household systems, which can be grid-connected or standalone. The literature reveals that solar PV is playing an important and large part in this transformation:

> *Renewable and PV in particular is changing the traditional view of the electricity supply chain – moving from delivery of a centralized source of energy to one that is decentralised and bi-directional (Salvoldi 2015).*

3.1. ALTERNATIVE POLICY APPROACHES

3.1.1. Scale of the projects

There are two key approaches that have been followed internationally to develop grid-connected solar programmes. These are utility or third-party programmes, and customer-driven programmes (Garg 2014: 26).

Utility/third-party driven programmes. Projects are undertaken by utilities or third-party developers to address regulatory and policy requirements such as renewable purchase obligations. Typically these projects are megawatt scale and there is a focus on cost optimization. If third parties develop these projects they typically enter long-term power purchase agreements with the utility. Customers ultimately pay for the cost of procurement.

Customer-driven programmes. Projects are undertaken by consumers on their own premises, due to the creation of facilitating policies and regulations by governments and regulators. These programmes refer to SSEG, and Garg (2014: 26) notes that these programmes have become increasingly popular because of the decreased costs of solar PV, fiscal incentives and the increasing costs of grid-based conventional electricity.

Most international solar PV markets are a combination of large megawatt solar plants and SSEG on customer’s premises. To encourage the uptake of SSEG, governments have a basket of incentive policies which are discussed below.

3.1.2. Types of incentive policies

According to Song et al. (2016: 10-11) policies used by governments to incentivise the installation of solar PV systems can be grouped into two broad categories: (1) those that help investors to reduce the investment threshold, and (2) those that improve the solar PV investment return. These are discussed below.

[4] A mini-grid is a system that combines generation capacity and a distribution network. It includes mini-grids that are unconnected to the main grid (i.e. off-grid) and systems that are connected but able to operate independently (APP 2017: 45).

Helping investors to reduce the investment threshold. Examples here are the introduction of laws to boost and facilitate the application of SSEG installations, or financial support measures such as subsidising PV installations to reduce the initial capital outlay and the capital cost over the life of the system. Other financial support measures include low interest loans, public guarantees and tax abatement policies.

Improving the PV investment return. Net-metering[5] and net-FiT policies fall into this category, where utilities purchase excess electricity exported to the grid. These are discussed in more detail below. Alternatively, a PV electricity grant can be used to encourage distributed PV installation. This is used to encourage self-consumption of PV electricity.

3.1.3. Net-metering / Net-FiT policies

Around the world there are a number of schemes with different names in place to encourage the uptake of SSEG by electricity customers. Some schemes are essentially the same but are called different names in different places, other schemes have the same names but are subtly or overtly different in the places in which they operate. However, what these schemes have in common is that they are used to encourage investments in solar PV (or other renewable energy technologies) by allowing electricity customers (both households and businesses) that install SSEG to be compensated for electricity they supply to the grid. In this paper we briefly describe net-metering and net-FiT as these are two of the most popular compensation mechanisms. Note that electricity consumed from the grid is referred to as imports, whilst electricity fed onto the grid is referred to as exports. Also note that a net-metering or net-FiT customer is still considered to be an electricity consumer and not a producer (such as an Independent Power Producer (IPP).

Net-metering (or net-billing). Under a net-metering or net-billing scheme customers with SSEG receive credits for excess electricity exported to the grid (i.e. the amount they produce above the amount they consume), which can be used to offset consumption in other billing periods. Under net-metering, the import rate and export rate are the same i.e. customers typically receive credit at the level of the retail electricity price. However, under net-billing, the export rate is lower than the import rate i.e. customers typically receive credit for excess power at a rate that is lower than the retail electricity price. However, as mentioned above, different jurisdictions may apply these terms in different ways (Ren21 2016: 267). A single bi-directional meter is needed to measure both energy usage and any exports (Salvoldi 2015).

Feed-in policy (feed-in tariff or feed-in premium). This is a policy that typically guarantees SSEG customers specified payments per unit over a fixed period, normally around 20 years. Numerous options exist for defining the level of incentive, such as whether the payment is structured as a guaranteed minimum price (e.g., a FiT), or whether the payment floats on top of the wholesale electricity price (e.g., a feed-in premium) (Ren21 2016: 266). Typically the export rate is initially set at a

[5] Note that gross-metering is also sometimes used, where all electricity generated is exported to the grid, and the household or business effectively becomes an IPP.

higher price than what the utility pays for energy in order to encourage uptake. As with net-metering, a single bi-directional meter is needed to measure both energy usage and any exports (Salvoldi 2015).

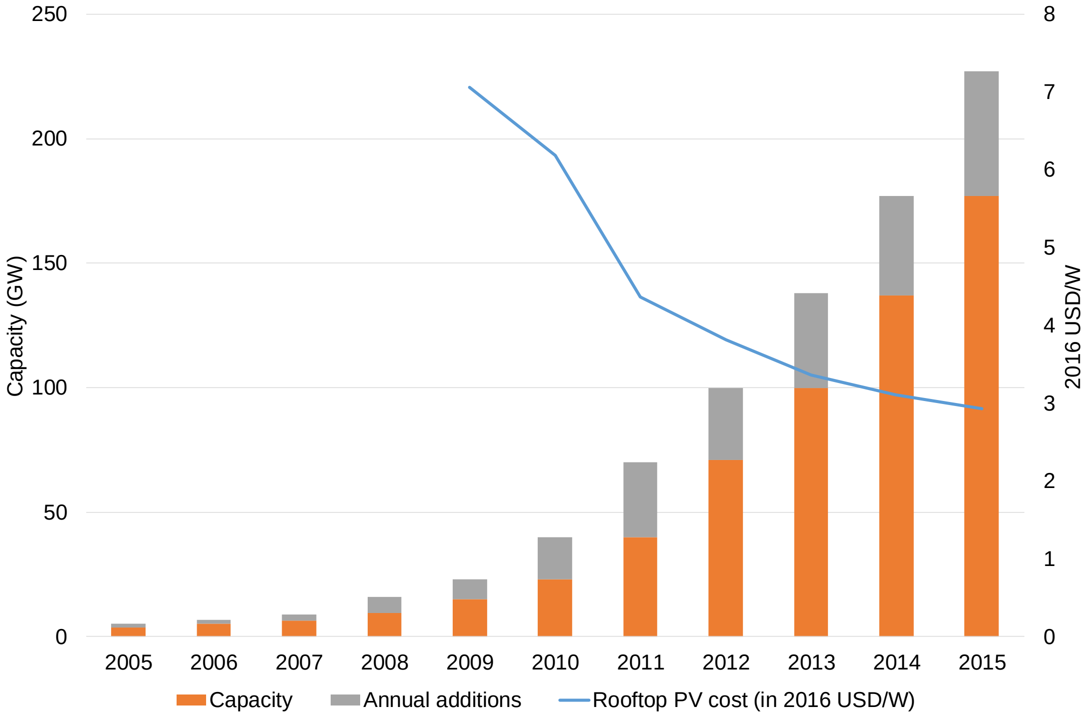
3.2. GLOBAL SOLAR PV CAPACITY INSTALLED

Globally, installed solar PV capacity has been growing exponentially over the last decade, and in 2015 installed capacity was 227 GW. 50 GW of capacity was added in 2015, which is nearly 10 times the size of cumulative world capacity a decade earlier (Ren21 2016: 60). Until recently, demand was concentrated in the developed world, but now capacity additions in emerging economies across the world are contributing significantly to global growth. Ren21 (2016: 60) notes that:

> *Market expansion in most of the world is due largely to the increasing competitiveness of solar PV, as well as to new government programmes, rising demand for electricity and improving awareness of solar PV's potential as countries seek to alleviate pollution and CO_2 emissions.*
>
> *[Emphasis added.]*

The chart below shows global capacity over the last decade and rooftop PV prices from 2009. As prices have come down capacity has grown exponentially.

Figure 3: Global capacity of solar PV and rooftop PV cost



Source: Capacity from Ren21 (2016: 62); Rooftop PV cost from NREL (2016: v).

Note: that the rooftop PV cost is for a residential installation of 5.6 kW; capacity refers to all solar PV installations and not just rooftop PV.

The chart above shows total solar PV capacity installed, and does not distinguish between rooftop and other installations. But country specific data illustrates that there is significant rooftop PV and other small-scale solar PV installations as a proportion of total installed solar PV capacity. For example, in Germany in 2012, 60% of its installed capacity was on rooftops – 9% (1-10 kW) on private buildings, 26% (10-100 kW) on social, commercial and agricultural buildings, and 24% (above 100 kW) on large commercial buildings. And in the USA, almost 30% of their installed solar PV capacity is on residential buildings, with the average size of these installations between 2 and 5 kW. (Garg 2014: 26).

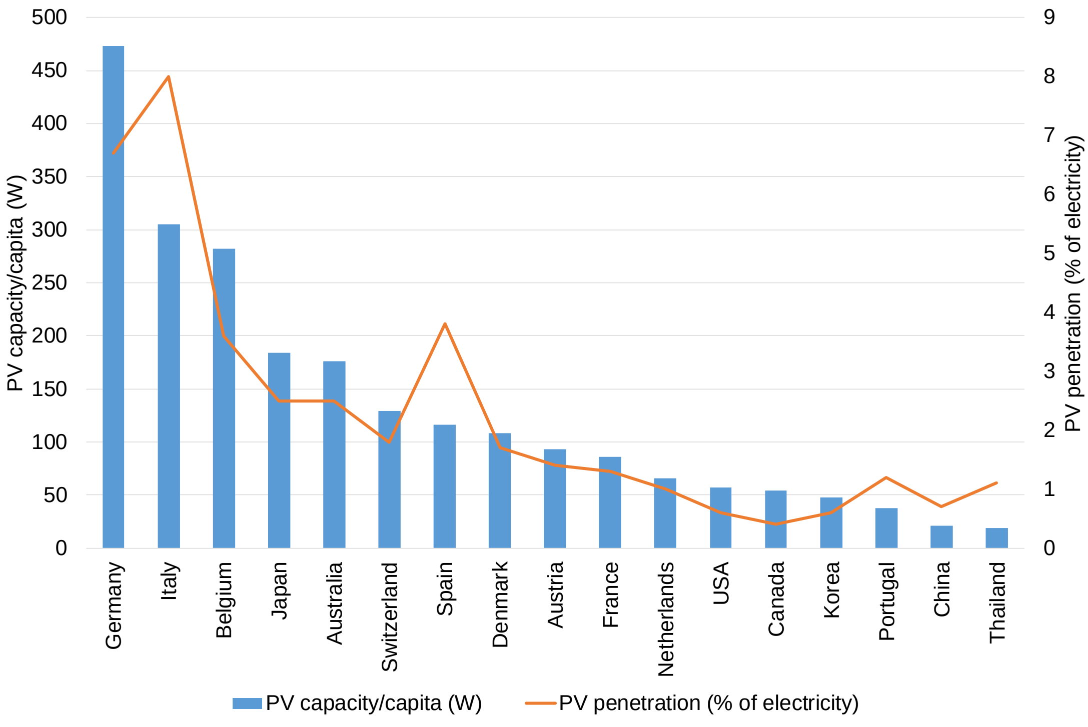
3.3. HISTORY OF THE ROOFTOP PV INDUSTRY

Net-metering originated in the United States in the early 1980's when owners of small renewable power units wanted to use the electricity they produced at times other than when it was being produced. The first scheme was introduced in Minnesota before spreading across the USA, and the first schemes in Europe were set up in Denmark, Italy and Spain.

Presently, over 35 years later, there are net-metering or feed-in tariff policies in place in 103 countries. There are government programmes in 44 of the 49 high income countries, 31 of the 44 upper-middle income countries, 24 of 36 lower-middle income countries and 4 of the 17 low-income countries reviewed in the Ren21 Global Status Report (Ren21 2016: 119-121).

Today the leaders in SSEG in terms of PV capacity/capita are Germany then Italy and Belgium. The chart below shows solar PV capacity/capita and PV penetration i.e. the proportion of solar PV generated electricity in the total electricity produced in a country. The chart shows the top 18 countries globally, which comprise European countries, Asian countries, the USA and Canada and Australia.

Figure 4: Solar PV capacity/capita and PV penetration



Source: IEA PVPS National Survey Reports[6].

A brief history of the rooftop PV experiences in Germany, Italy, Japan, the USA and China follow, after which a detailed case study of the South African experience will follow. South Africa is currently in the midst of having net-metering tariffs developed and approved which makes this case study particularly interesting and relevant.

Germany

Despite not being known as a sunny location, Germany is the world leader in solar installations. It has the highest PV capacity per capita and at the end of 2016 the total nominal PV power installed in Germany was 41 GW. On weekends the power supply from PV can reach up to 50% of momentary national power supply, and on weekdays 35% (Worth 2017: 6).

This can be explained by public support for "'de-fossilizing' Germany's electricity sector" (Weiss 2014: 40) and enabling legislation. In 1991 the Grid Feed-In Law was passed, and the very successful "The Thousand Solar Roofs Programme" was formulated. This programme was the first major solar installation initiative in the world, and it subsidised up to 60% of the solar PV system's costs. The programme was carefully monitored and issues such as financing barriers, grid technical standards and incentive levels were addressed in subsequent phases (Garg 2014: 31).

The Renewable Energy Sources Act (EEG) was enacted in 2000 and has been revised a number of times to accommodate the unexpected growth in installations.

[6] Data obtained from: http://theconversation.com/factcheck-qanda-is-australia-the-world-leader-in-household-solar-power-56670. [Last accessed 11/06/2017].

Essentially, the German programme consists of FiTs, which are fixed for 20 years, for PV installations of a range of sizes, from rooftop PV to utility-scale installations. Transmission System Operators (TSOs) are required to purchase all power produced and then on-sell the power on wholesale markets. A renewables levy is charged to most customers (heavy users in trade sensitive areas are partially exempt) which is then passed on to the TSO (Weiss 2014:1).

In 2012 the new EEG law came into effect with the aim being to transition the industry to a “new, incentive free policy paradigm” (Song et al. 2016: 6). Changes comprised a cap on total installed capacity, the reduction of the FiT and a limit to the amount of electricity exported to the grid.

Italy

Italy has the second largest PV capacity in the EU at 18.9 GW, which amounted to 9% of national electricity generation at the end of 2015. Italy implemented its first PV incentive policy, the “Photovoltaic roofs” programme, in 2001. The programme provided financial support, up to 75% of the total capital costs of installing a PV system with peak power between 1 and 20 kWp[7] (Song et al. 2016: 7).

Since 2001 a number of additional PV incentive policies have been implemented including a FiT scheme introduced in 2005 giving PV owners the option of selling the electricity exported to the grid. A net-metering scheme was also introduced for systems with a peak power up to 20 kWp. In 2009 the government extended the net-metering scheme to PV systems up to 200 kW; ensuring PV system owners receive the same price for the electricity produced and consumed from the grid. Under the FiTs scheme, the PV system owner receives a credit for the value of the electricity if there is an excess of electricity fed onto the grid. PV system owners also receive a premium FiT on the total electricity produced by the PV system (Greenpeace & European Photovoltaic Industry Association [EPIA] 2011: 53; Song et al. 2016: 7).

Japan

Japan was one of the first countries to develop and apply solar PV. In 1994, the Japanese government introduced a National Subsidy for Residential Buildings programme, which involved government subsidising up to 50% of the costs of installing a PV system for systems with installed capacity less than 5 kW. However, over time the profitability of PV electricity generation decreased owing to the decreasing value of the PV installation subsidy and the government failing to follow up with new subsidy policies (Song et al. 2016: 5).

In 2009 the government made efforts to revive the PV energy sector through the reinstatement of the national subsidy for residential PV systems, along with a new programme to purchase surplus PV electricity. By the end of 2009, almost 99% of the

[7] kWp stands for kilowatt peak which is peak power, and it refers to the amount of electricity a certain solar panel is able to generate. The kWp value specifies the output power achieved by a solar panel under full solar radiation (under set Standard Test Conditions). Solar radiation of 1,000 watts/m^2 is used to define standard conditions. (http://www.solar-is-future.com)

PV systems installed in Japan were grid connected, distributed applications, mainly residential PV systems (Greenpeace & EPIA 2009: 54).

The USA

With the development of PV technology and to promote the application of building integrated PV systems, the USA government launched the “10 million Solar Roofs Programme” in 2010 (Song et al. 2016: 9). The programme involved consumer rebates for the purchase and installation of rooftop PV systems.

Over 2008 and 2009, the government also introduced approximately 40 new solar incentive programmes across 19 states. The solar incentive programmes included production incentives, FiTs and renewable energy credit (REC) purchase programmes. In addition, local governments introduced Property-Assessed Clean Energy (PACE) programmes, which offered loans to property owners to help pay for PV systems (Greenpeace & EPIA 2009: 54).

China

The Chinese government has relied on a range of policy instruments to promote solar PV development including the Renewable Energy Law (REL) enacted in 2005. The REL set a national target for renewable energy development, in which grid companies were mandated to purchase all renewable electricity at a price higher than coal-fired electricity. A specific fund was also put in place to provide additional financial support for renewable energy development (Song et al. 2016: 7).

In 2009, the government attempted to elevate China’s solar rooftop programme with a number of measures, including the “Golden sun programme”, where it committed to undertake 50% of the investment costs for on-grid PV systems, and 70% of the costs for off-grid PV systems.

The implementation of installation subsidies, provided by the solar roof and Golden sun programmes, has contributed towards the rapid growth of China’s PV industry; the cumulative installed capacity increased from 300 MW in 2009 to 17,800 MW in 2013 (Greenpeace & EPIA 2009: 55).

3.4. SOUTH AFRICAN CASE STUDY

Over the last decade or so there has been increased interest in SSEG in South Africa. This is due to the decreasing price of solar PV rooftop systems, increases in electricity prices and the electricity supply crisis of 2008, which resulted in “load shedding”. As a result, electricity consumers started to install rooftop PV in increasing numbers, and in September 2016 it was estimated that there was over 200 MW installed over thousands of installations (Spencer 2016). Municipalities across South Africa have had requests for consumers with rooftop PV to connect to the grid and feed excess energy onto the grid. In August 2016, official data shows that there were 621 installations across the country connected to the grid, totaling 38 MW at an average size of 62 kWp (Gross 2017).

The connection of SSEG systems to the national grid has proved to be complex territory for municipalities. Municipalities need to ensure that the grid is stable and that safety standards are upheld, which means that consumers who want to connect to the grid have to comply with certain standards, which adds to the cost of a system. At the same time, the municipalities realise that if enabling policies are not in place, consumers will connect to the grid via unofficial channels, which has happened to a certain (unknown and unquantified) extent in South Africa. To date 25 of South Africa's 184 municipalities that are licensed to on-sell electricity keep track of existing installations, 18 have an official application programme and 12 have approved SSEG tariffs in place (Gross 2017).

SSEG tariff design in terms of setting the import and export tariff to the correct level is critical in ensuring that municipalities do not resist putting enabling policies in place to allow electricity consumers to connect their rooftop PV systems to the grid. For many South African municipalities revenue from electricity sales is an important component of its income and has multiple uses. It is used to maintain and operate the grid, cross subsidise tariffs from different sets of users (e.g. from industries to households), subsidise indigent tariffs and used to finance other service delivery where revenues do not cover costs (Ferry 2015). Thus municipalities may be resistant to consumers installing SSEG systems as it reduces its electricity sales. However, there are opportunities for municipalities to reduce costs (less bulk power purchases from Eskom and a reduction in technical losses) plus municipalities can on-sell the excess electricity that is fed onto the grid from SSEG customers at an increased margin to other customers (provided the export tariff is lower than the bulk electricity purchase price from Eskom). The correct level of SSEG tariffs ensures that allowing rooftop PV customers to connect to the grid has only the desired impact on municipal finances. Carefully designed tariffs can help towards achieving revenue neutrality whilst still ensuring a positive business case for electricity consumers who are considering installing solar PV.

In South Africa there has been regulatory uncertainty at a national level as municipalities and consumers wait for guidance from the National Energy Regulator of South Africa (NERSA). NERSA issued a consultation paper in February 2015, but to date regulatory rules are still to be published. However, the South African Local Government Association (SALGA) has a number of guiding principles on SSEG, and (as discussed above) has assisted a number of municipalities in the design of SSEG tariffs. SALGA's guiding principles to municipalities comprise the following (Ferry 2015):

- Municipalities should minimize illegal or informal connections by providing a sufficient incentive to formally connect to the grid in terms of a decent export tariff;

- Solar PV uptake should be encouraged by lowering the administrative burden to potential installers, providing security of investment in the form of a guaranteed tariff and providing low overhead costs for any new equipment required by customers such as meters;

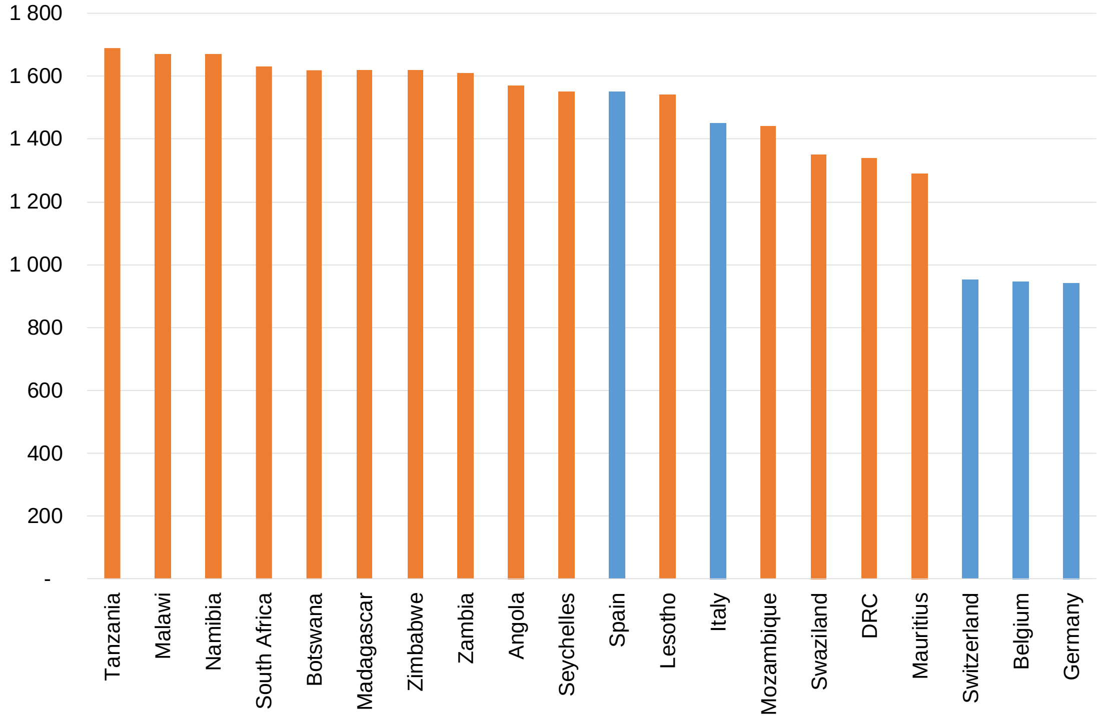
- The costs to the municipality should be limited by ensuring that the export tariff is not too high and that grid costs are covered fairly by all users regardless of whether or not they are SSEG customers;
- Municipalities should aim to decrease peak consumption by designing tariffs that provide an incentive for the timely use of electricity.

4. HOW ROOFTOP PV CAN ASSIST IN SOLVING THE ENERGY CRISIS IN SADC

4.1. SOLAR RESOURCES

The discussion above illustrates that developed countries with enabling policies in place are at the forefront of SSEG worldwide. And this is despite the fact that these countries enjoy far less sunshine than what SADC countries do. Next we show solar resources for the top five European countries (as shown in Figure 5 below) as well as for the fifteen SADC countries. What is immediately clear is that SADC's solar resource potential is far greater than that of Switzerland, Belgium and Germany. Spain and Italy have better solar resources than the three aforementioned countries, however the majority of SADC countries still enjoy better sun than Spain and Italy.

Figure 5: Average annual electricity production from a 1 kW system (kWh)



Source: Solar generation data from the PVGIS-CMSAF solar radiation database[8] .

[8] http://photovoltaic-software.com/pvgis.php. Last accessed 11/06/2017.

4.2. IMPACT ON ENERGY SECURITY

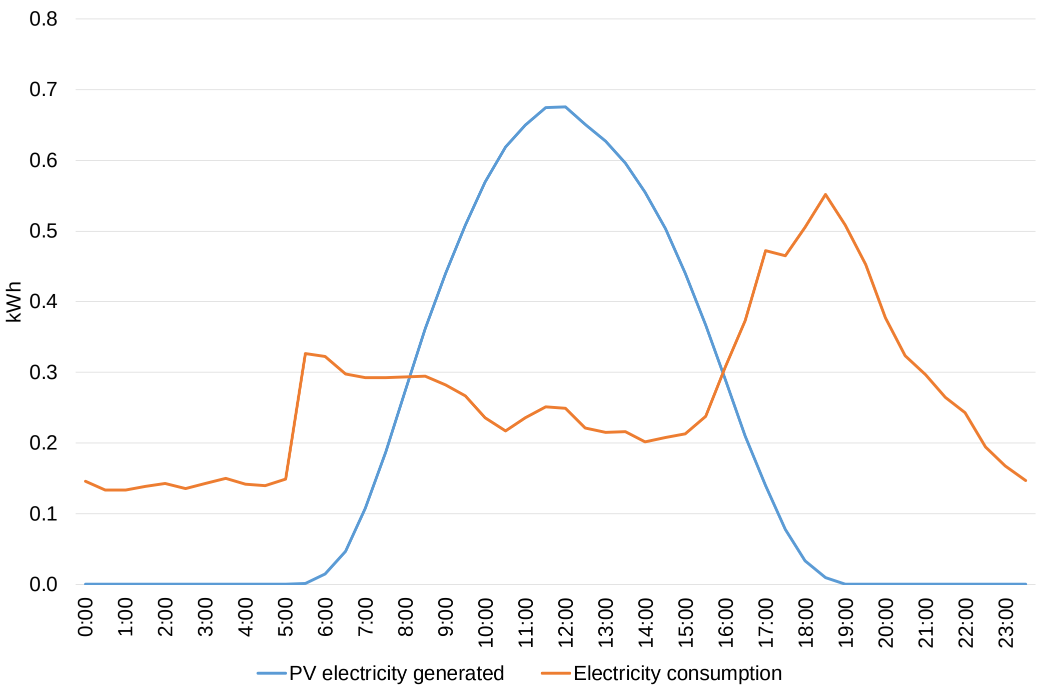
The impact of a rooftop PV programme depends on the solar resource potential in a particular area; the technical potential of a system in terms of how many kWh of electricity it can produce given the available solar resources and the performance of that particular system; and the economics of the programme in terms of whether it makes financial sense to both the SSEG customer and utility/municipality. The economics is dependent on the regulations and policies that are in place.

It is useful to revisit the definition of energy security when assessing how a rooftop PV programme can improve it. It is defined as "the uninterrupted availability of energy sources at an affordable price", and thus combines the concepts of uninterrupted supply and cost-effectiveness. Solar PV goes some way in addressing these elements, however it must be stressed again that it would be most effective as a basket of alternatives that governments can use to improve access and affordability issues in their respective countries.

Uninterrupted supply

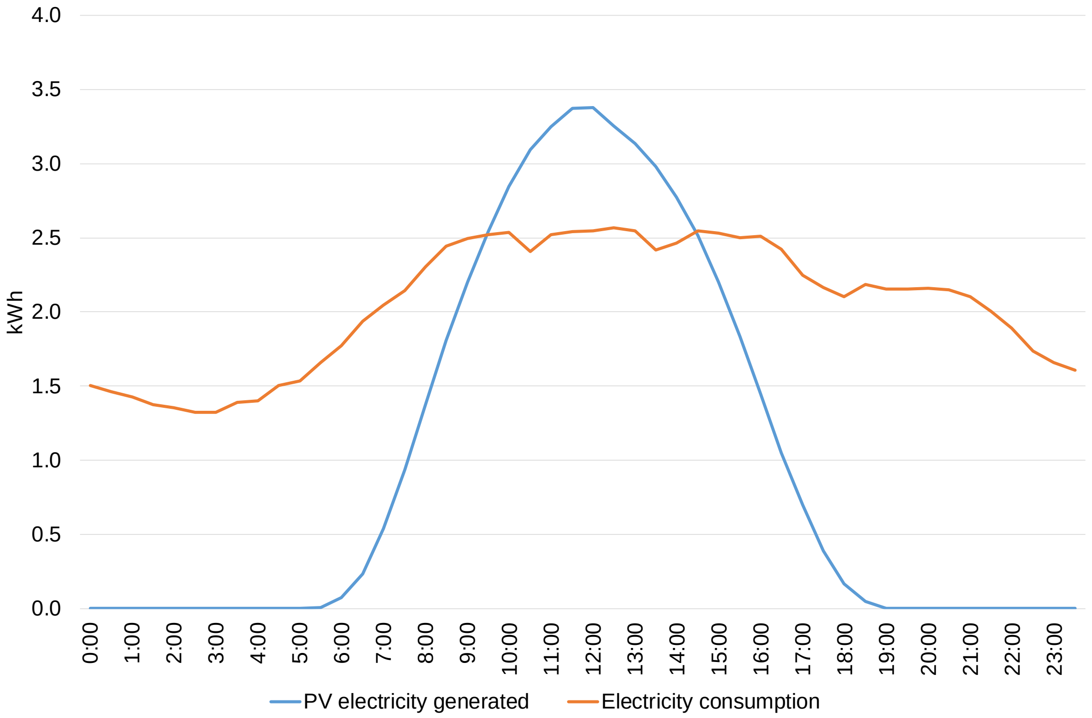
Solar PV generates electricity during sunlight hours, and thus without battery storage (which may however become a reality in the future) it is confined to certain hours of the day. The diagram below shows solar PV output over a typical 24 hour period, with the consumption profile of a typical household. Thus during sunlight hours those households and businesses with rooftop PV are ensured an uninterrupted supply of electricity, provided the correct size of PV system is installed. In addition, if excess electricity is generated and fed onto the grid, this can be on sold to other customers which in turn impacts upon those customers access to uninterrupted power.

Figure 6: Electricity generated and consumed for a household on a typical summer day



Source: chart was generated using a model developed by the authors to determine the financial impact of SSEG on municipalities in summer; PV electricity was generated using data for a 2 kWp system installed in Pretoria, and consumption is based on load profiles generated using Eskom data for a fictional customer.

Figure 7: Electricity generated and consumed for a small business on a typical summer day



Source: chart was generated using a model developed by the authors to determine the financial impact of SSEG on municipalities in summer; PV electricity was generated using data for a 10 kWp system installed in Pretoria, and consumption is based on load profiles generated using Eskom data for a fictional customer.

Cost of electricity

The element of cost effectiveness depends on the initial investment required by the electricity customer who chooses to install rooftop PV, plus the tariffs that are put in place. As we discussed in the South African case study, it is a delicate balancing act for municipalities to design tariffs at the correct level so as to incentivize PV uptake whilst ensuring minimal impact on municipal finances.

Thus, rooftop PV means greater security of electricity supply for those customers that have installed it, plus less blackouts for these and other customers (as demand from the utility is reduced and total available supply is increased). Thus the increased uptake of rooftop PV across SADC will help to address SADC's energy crisis.

As discussed in Section 2, greater security of electricity supply will contribute towards economic development, productive employment, job security and income generation. In addition, it will contribute towards enhancing food security among the poor through technologies that can be used for irrigation and water pumping and also provide a reliable and sustainable source of energy for household cooking. Increased security of electricity supply will also provide educational and health benefits among the poor.

4.3. BENEFITS TO STAKEHOLDERS

4.3.1. Government and Regulators

Electricity generated by solar PV is a reliable, cost-effective and clean solution to an energy crisis, and is accessible to a large number of people. If it is properly planned and implemented, it can help solve energy shortages at the household and business level. Governments need to decide on an appropriate roll-out model in order to ensure that it is financially and technically feasible and that the sector is sustainable in the long-run and able to self-replicate (Garg 2014: 112).

4.3.2. Rooftop owners

For rooftop owners, whether they are households or businesses, the key benefits of installing a rooftop PV system are using an idle rooftop space to generate electricity, savings on utility bills or earning additional income if exports exceed imports (and payments to customers are allowed under the relevant scheme). However, there are a number of considerations that a rooftop owner faces, and these are listed below:

- The financial viability of the PV system. That is, is there a positive business case for the electricity customer who is contemplating installing solar PV;
- The stability of the grid in terms of whether it is able to accommodate PV connections;
- In addition there are practical considerations such as whether permission is required to install the system, if there are third parties available to install and maintain the system and whether there are any other technical aspects that need to be taken into account (Garg 2014: 113-114).

4.3.3. The utility

Rooftop PV is most beneficial to utilities when there is a good match between consumption peaks and solar peaks, especially if the utility is currently facing power shortages in peak demand periods. Because rooftop PV injects power at the “tail-end” of a distribution system i.e. point of consumption, it also helps in voltage regulation and loss reduction. However, there are some issues which a utility needs to monitor closely, such as impact on revenues, stability of the grid and safety issues, especially if the uptake of rooftop PV is significant. Despite these challenges, Garg (2014: 116) suggests that “(i)n the long run, it makes sense for the utilities to be willing participants in this market rather than view themselves as victims of this expanding global phenomenon.”

5. POLICY OPTIONS AND STATUS

Clear measures are crucial for creating a successful renewable energy policy which offers long-term security of supply and stability. Greenpeace and EPIA (2011) have developed key recommendations for policy-makers to implement adequate support schemes for rooftop PV. One of the recommendations put forward is using FiTs or similar mechanisms. FiT laws introduce the obligation for utilities to conclude purchase agreements for solar electricity generated by PV systems. In markets where FiTs were introduced as reliable and predictable market mechanisms, they have proven their ability to develop a sustainable rooftop PV industry that has progressively reduced costs towards grid parity. In order to be sustainable, it is critical that FiTs are guaranteed for a significant period of time, at least 20 years, without any possibility of retroactively reducing them.

It is important to promote the development of a sustainable rooftop PV market by assessing profitability to the electricity customer on a regular basis. A critical aspect of sustainable development is ensuring adequate levels of profitability. All available support schemes (including FiTs, tax rebates and investment subsidies) must be taken into account when calculating the return on a rooftop PV investment.

With the ongoing decrease in installed rooftop PV system costs and the increase in conventional electricity prices, Greenpeace and EPIA (2011) suggest that the use of financial incentives should progressively be phased out, as competitiveness is reached. Therefore, a roadmap to grid parity should be defined for every country.

5.1. POLICIES IN PLACE IN THE SADC COUNTRIES

All SADC member states have introduced specific policies to encourage renewable energy development, and many have FiT or net-metering policies in place. This section summarises incentive policies for SSEG in place in various SADC member states. An area for further research is how successful these policies have been, and what the actual uptake of rooftop PV in the SADC member countries is. The table below shows the existing SSEG incentive policies in place.

Table 2: Renewable energy and SSEG policies in place in SADC member states

		SSEG policy	
	Renewable energy policy	Feed-in Tariff	Net-metering
Angola	X	X	
Botswana	X	X	
DRC	X		
Lesotho	X		X
Madagascar	X		
Malawi	X	X	
Mauritius	X	X	
Mozambique	X	X	
Namibia	X	X	X
Seychelles	X		
South Africa	X		X
Swaziland	X		
Tanzania	X	X	
Zambia	X		
Zimbabwe	X	X	X

Source: Adapted from Ren21 (2015).

Angola

The Government of Angola recently approved the National Strategy for New Renewable Energy with the objective of diversifying investment in renewables. Some of the goals set forth in the strategy include developing the use of renewable energy technologies connected to the grid and promoting private and public investment in renewable energy technologies (Angola Energy 2017). With respect to SSEG, the strategy includes provision for establishing subsidised feed-in tariffs for renewable energies, of up to 10 MW, connected to the grid; taking into account the applicable tax system, the type of financing and respective interest rates. It is envisaged that these subsidised tariffs will be decreased to ensure the sustainability and competitiveness of renewable energy in the future.

In addition, there are provisions for the establishment of renewable energy IPPs and a tender process will be launched to issue licenses for the construction of PV power plants connected to the grid, with a total capacity of 100 MW, 10 MW per year over 10 years.

Botswana

In 2010, the Department of Energy Affairs in Botswana commissioned a study on renewable energy FiTs, identifying significant potential for generating power from solar PV, in addition to other renewable energy technologies. The launch of the renewable energy FiT programme, however, was delayed and few details about the policy have been announced (Beetz 2015). Nonetheless, Botswana's National Development Plan 2009 – 2016 outlines the country's commitment to improved energy access through increased supply and availability of electricity. Given the planned structure of FiTs and its inclusion of small-scale generation (≥ 5 MW), the policy could positively impact decentralised generation and community participation in the country (Nganga, Wolhert & Woods 2013: 77).

Democratic Republic of Congo

The Democratic Republic of Congo is looking into developing and promoting the use of renewable energy resources such as solar PV through its development programme to be fully implemented by 2030. However, apart from the above, there is no clear policy supporting the development and implementation of rooftop solar PV (Kusakana 2016).

Lesotho

The government of Lesotho developed the Lesotho Energy Policy 2015 – 2025. One of the objectives in the power generation sub-policy is to develop indigenous renewable energy resources (Lesotho Energy Policy 2015: 11).

With respect to rooftop PV SSEG, supporting strategies in the policy include encouraging the participation of the general public in large, mini and micro-solar; the development of a power purchase agreement framework that will enable the private sector to participate as IPPs in mini or mico solar; and the introduction of a net-metering system (Lesotho Energy Policy 2015: 11).

Madagascar

Madagascar's Tax Code of 2015 includes a number of fiscal incentives for small and large scale investments in the production and distribution of renewable energy including a reduction in corporate income tax equivalent to 50% of the renewable energy investment undertaken; and a VAT exemption for equipment used for the production of renewable energy. The list of products exempt from VAT includes solar PV panels, wind power generators, and hydropower generators (IEA 2016).

Malawi

The Malawi Energy Regulatory Authority (MERA) introduced a FiT policy as part of its efforts to promote renewable technologies. MERA developed a guiding framework on FiTs for electricity generation from various renewable energy sources to promote private and small scale participation in energy production and supply and also to boost the development of renewable energy sources (Mwagomba 2015: 5).

The policy has been designed in such a way it enables power producers to sell generated electricity to a distributor at a pre-determined fixed tariff for a given period of time.

Mauritius

In 2010 the Small Scale Distributed Generation (SSDG) scheme was launched in Mauritius. The SSDG scheme is a FiT scheme developed to support the deployment of small scale renewable energy installations up to 2 MW of new electricity generation.

The SSDG scheme is designed such that owners of small scale solar PV installations are eligible to export surplus electricity generated back to the grid in exchange for a FiT payment. If the amount of electricity exported to the grid is three times higher than the amount consumed onsite, in the following year the generator will automatically be switched to the Greenfield tariff which is 15% lower than the regular FiT rate. FiTs are granted for a period of 15 years (IEA 2013).

Mozambique

To support the development of renewable energy technologies, the Mozambique Ministry of Energy launched a renewable energy FiT scheme in 2014 (Beetz 2015). The scheme targets small-scale solar PV projects of 10 MW or less connected to the main grid (World Bank 2015).

Namibia

Namibia's FiT programme, drafted in 2013, is intended primarily for small to medium sized businesses in the generation of power from various renewable energy sources up to the maximum of 5 MW per business (Shilamba 2015). The FiT programme has a detailed tariff schedule with different tariffs for different facility sizes and for different renewable energy technology projects (Ren21 2015: 69).

Namibia has also instituted net-metering, limited to facilities with a capacity of 500 kVA or lower. The net-metering rules were developed to promote sustainable energy sources, small scale investments, value addition and electricity market development, and contributing towards reducing unemployment (Electricity Control Board 2016).

Seychelles

The Government of Seychelles together with the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) developed the Grid-Connected Rooftop PV Systems Project to jumpstart the PV market in Seychelles (PV Project 2017). The objective of the project is to increase the use of grid-connected PV systems as a means of generating electricity in selected islands of the Seychelles, with a focus on small-scale producers who are already connected to the grid (IEA 2013).

One of the major activities implemented under the project is the Financial Rebate Scheme. The Financial Rebate Scheme is designed to remove financial barriers that restrict adoption of PV by households and small to medium enterprises (PV Project 2017). In 2014, the Scheme offered a 35% rebate (based on the average cost of PV installed in Seychelles) to all homeowners for the first 3 kWp of a system installed onto the rooftops of their homes. In 2015, this value was reduced to 25% as the average cost of a PV installation dropped (PV Project 2017). A 15% Financial Rebate for commercial premises with installations up to 15 kWp was also introduced in 2015.

Swaziland

The Electricity Act in Swaziland allows for the supply of distributed renewable energy to the grid. However, there are currently no small-scale grid-connected PV systems in the country because of the absence of clear regulations and by-laws to guide and incentivize third party involvement in distributed PV. However, the Ministry of Natural Resources and Energy is working towards developing a FiT framework for small-scale distributed generation (IRENA 2014: 26).

Tanzania

In 2008, the Small Power Producers (SPP) framework was created in Tanzania to produce an enabling environment for private project development of projects up to 10 MW, through standardized power purchase agreements. SPPs can sell power to Tanzania's main grid or isolated mini-grids, wholesale or retail (Energy and Water Utilities Regulatory Authority [EWURA] 2015).

In 2015, EWURA approved the Second Generation SPP framework for Tanzania. There will be competitive bidding to establish tariffs for solar and wind projects and technology specific FiTs for small biomass and hydro projects. In addition, for both calculated FiTs and competitively bid FiTs, the cost-reflective tariffs will ensure the investor security by providing a fixed price for the duration of the small power purchase agreement, up to 25 years (EWURA 2015).

Zambia

The Government of Zambia offers tax incentives for small solar project developers, including VAT exemptions and tax holidays (Beetz 2015).

Zimbabwe

Zimbabwe introduced FiTs for renewable energy plants up to 10 MW to promote on-grid and off-grid PV applications (Africa-EU Renewable Energy Cooperation Programme [RECP] 2016). Zimbabwe's FiTs are based on a tariff close to the levelised cost of electricity for each technology. It includes purchase guarantees and a contract period of 25 years (Ren21 2015: 68). Tariffs vary according to the size of the facility and the technology.

The Zimbabwe Energy Regulatory Authority (ZERA) has also drafted net-metering regulations intended to govern the generation of electricity from small scale, grid tied renewable generators like solar PV generators on rooftops (ZERA 2016).

5.2. BEST PRACTICE

Policy support is key for the future development of the PV industry, for both the private investors and governments involved. This section outlines best practice by looking at the policies in place in leading solar PV countries.

As discussed in Section 3, leading solar PV countries have implemented a number of policy incentives to encourage the uptake of SSEG by electricity customers. Regarding financial incentives, net-metering and net-FiT have been implemented in all of the leading PV countries.

Additional financing measures that have been adopted are PV electricity grants. PV electricity grants aim to promote the self-consumption of PV electricity generated while transmitting surplus electricity on to the grid (Song et al. 2016: 10). Using electricity generated by PV systems can cut electricity bills; and the additional subsidy granted with the use of PV electricity enhances the return rate to investors.

Countries have also enacted laws to encourage the uptake of PV systems. Though necessary, laws tend to be a weak policy tool as they do not directly create investment but rather give investors and households a guiding framework in which to take action (Song et al. 2016: 11).

Investment programmes carried out by government or companies are strong policy tools. This is evidenced by the rapid increase in capacity after the rolling out of a PV programme by government (Song et al. 2016: 11). However, this kind of tool has a limitation when extended to residential PV systems, given that the household or building owner must be persuaded to install a PV system on the outside of their premises even though this does not produce direct profit and mars the appearance of the building.

Financing incentives such as FiTs and PV electricity grants stimulate PV investment programmes because they ease the capital burden on government, in turn releasing more civilian capital to invest in PV systems (Song et al. 2016: 11).

With the joint efforts of the leading countries in recent years, the cost of PV installations has dramatically reduced. Therefore, PV technology has become a significant and widely accepted source of renewable energy. Expensive initial investment for installation is no longer a major issue for many countries.

In order to quickly promote PV application, governmental supports to increase investment return, for example, FiTs and PV electricity grants, have progressively replaced government subsidies and have become the mainstream incentive policies implemented (Song et al. 2016: 11).

6. CONCLUSION

This paper discusses the energy crisis in SADC before explaining how SSEG, and rooftop PV in particular, can be used to improve the situation for households and businesses in SADC. Access to electricity is critical for economic growth, and the link between lack of access and poverty further highlights the urgency for improving uninterrupted access to affordable electricity supply to all SADC member states.

Renewable energy has the potential to improve the situation in SADC as well as contribute towards a greener future with less reliance on traditional fossil fuels. It has the dual benefit of simultaneously addressing the problems of climate change and energy security. Rooftop PV in particular is an attractive option as prices have fallen recently and the technology has improved, and it provides electricity at the point of consumption, thus reducing transmission and distribution costs. International experience has shown a successful uptake is highly dependent on the policies and incentives that are put in place by governments. Flexibility in government programmes is also key, as the solar PV market matures and different issues emerge, the programme needs to be able to flex to accommodate the changing environment.

This paper revealed that there are enabling policies in place in many SADC countries, but many have only recently been introduced. Further research is required in the future to determine the uptake of rooftop PV in these countries and thus to assess the effectiveness of any incentives put in place. At the same time electricity access and power outages can be tracked to see if the energy security situation is improving.

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