CONSULTANCY SERVICES FOR A STUDY ON SOLAR PHOTOVOLTAIC INDUSTRY IN KENYA

DRAFT FINAL REPORT

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ABBREVIATIONS AND ACRONYMS

KEBS	Kenya Bureau of Standards
ERC	Energy Regulatory Commission
KRA	Kenya Revenue Authority
KPLC	Kenya Power and Lighting Company Ltd
REA	Rural Electrification Authority
KIHBS	Kenya Integrated Household Budget Survey
RE	Renewable Energy
PV	Photovoltaic
KEREA	Kenya Renewable Energy Association
NGO	Non-Government Organizations
AH	Ampere-hour
kWh	Kilowatt-hour
A	Ampere
V	Volts
DC	Direct Current
AC	Alternating Current
kW	kilowatt
MW	Megawatt
IRENA	International Renewable Energy Agency
IEA	International Energy Agency
SHS	Solar Home System
ISHS	Integrated SHS
CSHS	Component based SHS
BOS	Balance of System
LCOE	Levelized cost of Energy
KShs	Kenya Shillings
BOS	Balance of Systems
PnP	Plug and Play

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EXECUTIVE SUMMARY

Introduction

The Energy Regulatory Commission (ERC) is the single energy sector regulator, with responsibility for economic and technical regulation of electric power, renewable energy, and downstream petroleum sub-sectors, including tariff setting and review, licensing, enforcement, dispute settlement and approval of power purchase and network service contracts.

The ERC is mandated to regulate the importation, production, distribution, supply and use of renewable and other forms of energy; protect the interests of consumers, investors and other stakeholders; collect and maintain energy data and provide information and statistics to the Minister as he may from time to time require.

Energy sector data and information is crucial in the formulation of appropriate policies and regulations that would better protect the interests of all industry stakeholders.

To execute its mandate of data collection and maintenance and to support its policy and regulatory initiatives, The ERC engaged Rencon Associates Ltd, a Renewable Energy and Energy Efficiency Consultancy Firm to undertake a study of solar PV industry market in Kenya.

The study commenced in April 2018 and this is the Draft Final Report.

Objectives of the Study

The overall objective of the study was to assess the current status of the solar photovoltaic industry in Kenya and globally, establish quality, capacity and performance of products and installed systems, identify barriers and regulatory gaps that hinder the growth of the industry and recommend measures to enhance the uptake of the technologies in the country.

The specific objectives were:

i) To identify the key players and products in the Kenyan solar PV industry;
ii) To determine the capacity of the solar PV systems installed in the country;
iii) To assess the performance of systems installed in the country and identify the key reasons of success/failure of installed systems;
iv) To identify the trends in the development of the solar PV technology locally and globally including financing models and other policy instruments adopted to promote the uptake of PV products;
v) Model the levelized cost of PV generated energy (LCOE) for solar home systems and solar water pumping;
vi) Identify challenges in the adoption of solar PV in Kenya;
vii) Identify justified skill requirements for developing the solar photovoltaic industry in Kenya;
viii) Identify any regulatory/policy gap in the development of the Solar PV technology market in Kenya;

ix) Prepare a policy brief on the status of the Solar PV industry in the country and future prospects.

Methodology

The assignment was executed through desk and field studies. A desk study was carried out to determine the trends in the development of the solar PV technology, international markets, policy and regulatory practices in other jurisdictions, financing options and general global market situation. The field study was carried out to assess and determine products in the market and their characteristics, capacity and performance of installed systems, to identify barriers and regulatory gaps that hinder the growth of the industry and related technical and market data and information. Data was gathered using structured questionnaires and interview guides administered through a combination of face-to-face and telephone interviews and the internet.

The gathered data and information were analysed using quantitative and qualitative statistical methods, and the results were interpreted to provide answers to the study questions.

Results

i) PV technologies and development trends – global market

PV Modules

PV technologies can broadly be grouped into three ï crystalline, thin film and multi-junction technologies.

There are two proven and predominant crystalline PV technologies, both based on Silicon solar cells. These are the mono-crystalline (Mono-Si) and multi-crystalline silicon (Multi-Si) PV technologies. The proven and commercialized thin film technologies are Amorphous Silicon (a-Si), Cadmium Telluride (CdTe), Gallium Arsenide (GaAs) and Copper Indium Gallium Diselenide (CIGS). Multi-junction technologies, utilizing both crystalline and thin-film, are being developed but have not yet been commercialized in any significant way.

Solar cell efficiencies have not always been good. Advances in semiconductors materials purification and processing and development of new cells and modules production methods have resulted in steady and impressive efficiency gains over the last 40 years.

Crystalline silicon cell efficiencies have risen from around 15% to the current confirmed efficiencies of 26% in about 30 years. This has been reflected on to the PV modules as well which have much higher output per unit area.

Due to the increasing cell efficiencies, improvements in production processes and material utilization and economies of scale, the price of crystalline silicon technology has declined exponentially over the last 40 years. In absolute terms, the price of solar cells has fallen from KShs 7600 per Wp in 1977 to the present KShs 30 per Wp, at the current exchange rate of KShs 100 to the US Dollar.

Balance of System Components

The gains observed for PV modules have also been observed for the Balance of system component, namely Inverters, Charge Controllers and solar batteries. Though not as dramatic as for solar cells, the efficiency gains on the BOS components have been impressive. This coupled with improvements in production processes and material utilization and economies of scale have also seen a continued decline in prices of BOS components.

Global Market Growth Trend

The net effect of the above developments is a dramatic decline in PV systems prices and an exponential growth of the global PV market as is seen in Figure 1.

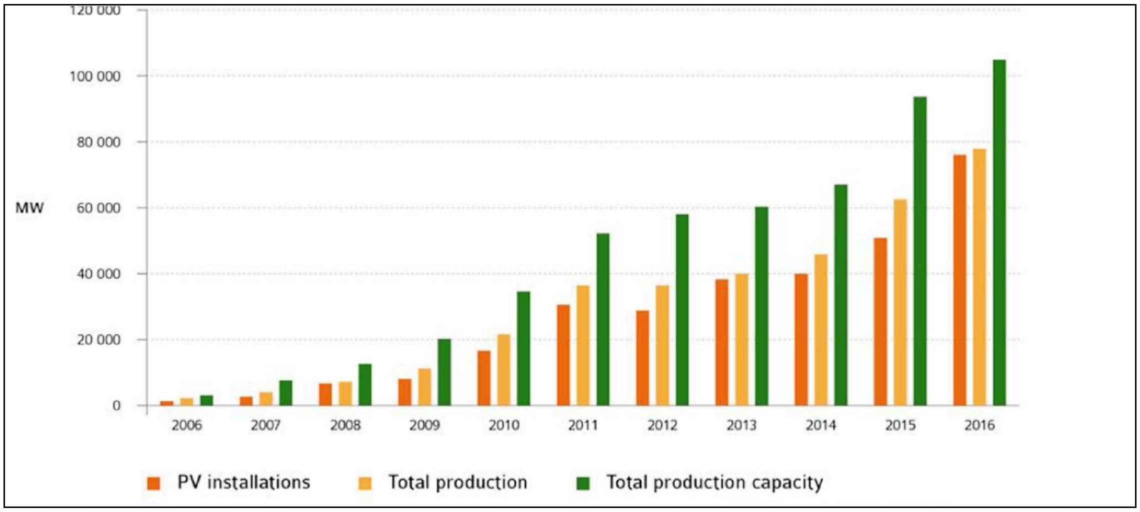

Figure 1: Global PV production and consumption trend, 2006-2016.

Major Global Market Players

PV module production is dominated by China, South Korea, Malaysia and Japan who produced 69%, 7%, 7% and 4% respectively in 2017. The top 10 manufacturers are Jinko (China), Trina Solar (China), Canadian Solar (Canada), Hanwha (South Korea), JA solar (China), LONGi Green (China), GCLSI (Hong Kong), Risen (China), Yingli (China) and Telesun (China).

In terms of consumption, Asia is now the leader of the Global PV market. China, India and Japan lead the pack. In the Americas, the US market is commanding the lead followed by Brazil. In Europe, Germany followed by UK, France, Netherlands and Italy in that order are the main PV markets. In the Middle East, Turkey followed by Israel, UAE and Saudi Arabia are the major markets.

In Africa, South Africa and North African countries mainly Algeria and Egypt are the leaders but most high-power projects are still under development. Kenya is completing a 50MWp project and others are in the early stages of development.

Global Market Drivers

The exponential global PV market growth has been driven by two key factors. The plummeting PV prices and policy driven market incentive schemes by Governments. The main policy incentives that have been employed by governments to develop PV markets are:

- Feed-in Tariffs
- Direct subsidies or rebates
- Tax breaks
- Net-metering
- Self-consumption
- Energy auctions
- Trading of green certificates
- Regulations
- Electrification targets
- Quality Assurance frameworks

Feed in tariffs and direct subsidies and tax breaks have been most successful market support mechanisms for PV. Combined, they support 81% of the global PV markets.

ii) Local market development and growth prospects

The Kenya PV market started off in the seventies as a specialist PV systems service to provide power to telecoms OEMs and utilities for use at radio repeater and TV booster sites located in remote areas without grid connection. The benefits of PV for remote power use was then captured by United Nations bodies such as UNICEF and NGOs working in remote areas such as Oxfam. UNICEF and the Ministry of Health started replacing Kerosine Vaccine Refrigerators in remote area health centres and providing basic lighting and NGOs started using PV power in their remote offices. As PV awareness rose other institutions such as schools that could afford or got financiers (mainly NGOs) started to install solar systems. As awareness spread, individuals who could afford the systems started acquiring them for their households as grid connectivity was extremely low and fairly expensive.

The declining PV prices, introduction of quality standards by the Government, training of technicians and marketing and promotion initiatives by companies, NGOs, and international programmes such as photovoltaic market transformation initiative fuelled the market growth. The inclusion, in 2006, of PV as a rural electrification alternative by Ministry of Energy in order to accelerate the electrification of public institutions raised the demand dramatically.

Since Kenya was not a PV modules or devices producer until recently and most companies continue to import, then historical evaluation of importation statistics from KRA are a good indication of local PV market trend. The 8-year imports are illustrated in the Figure 2.

It should be noted that the Harmonised Coding system that classifies products includes transistors, solar cells and other photo-sensitive devices in the same code number as PV modules. The assumption in this chart was that the imported devices were PV modules or had a PV module as part of the device e.g. solar lantern.

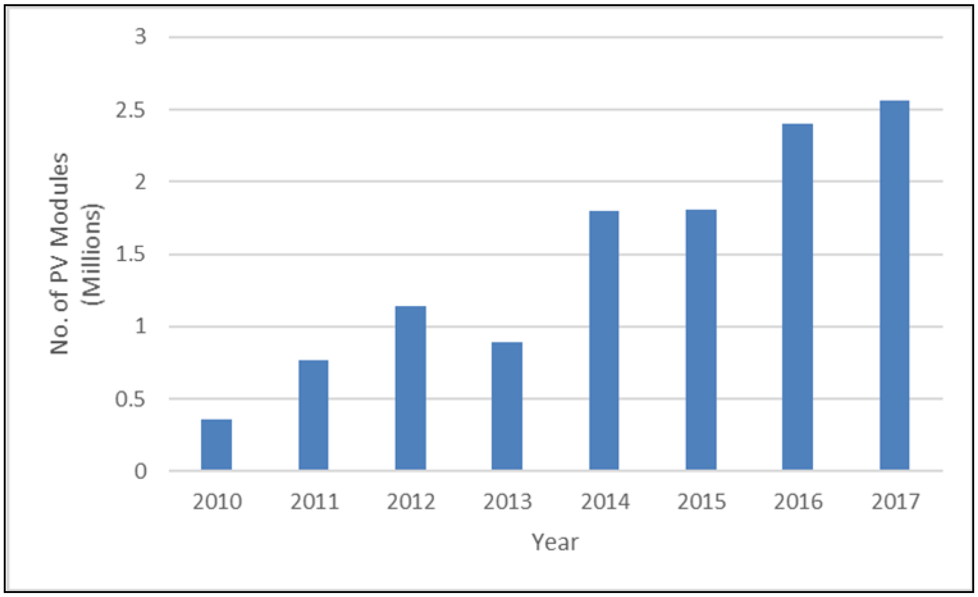

Figure 2: Annual PV module imports trend, 2010-2017.

Using the same assumptions as above together with prevailing prices during that period, an estimate of the demand trend in terms of power capacity was made and the same for the last eight years is illustrated in Figure 3.

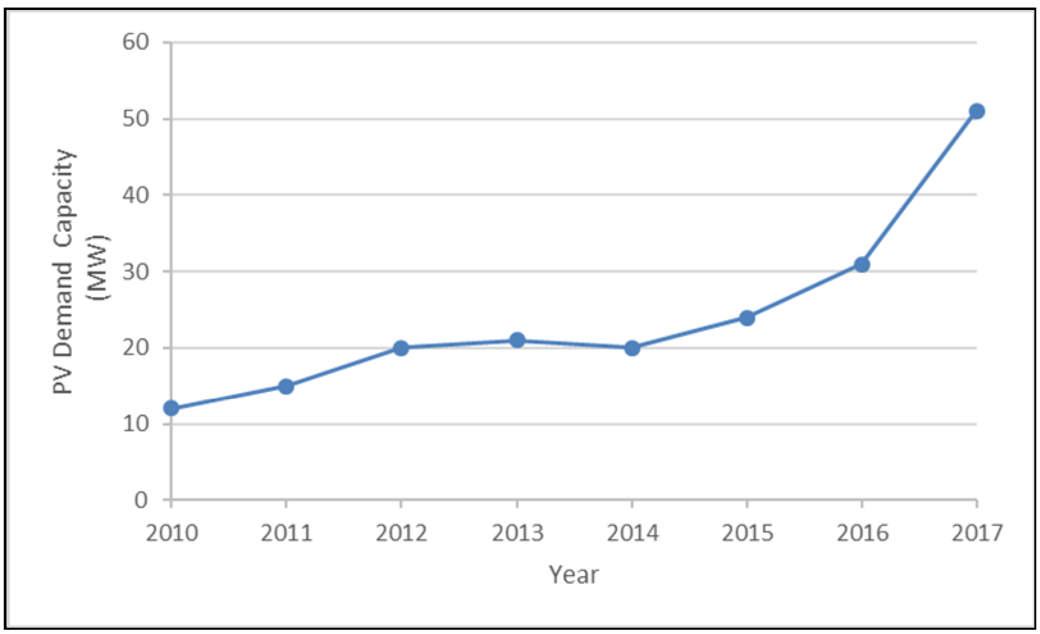

Figure 3: Annual estimated local PV demand capacity trend, 2010-2017.

Figure 3 shows that the market has had an almost linear growth of about 30% per annum up to 2016. Some grid-connect projects have been undertaken locally since 2014 and there has been a tremendous growth in the uptake of solar lanterns and SHS driven by the World Bank supported Lighting Africa programme. These two have certainly contributed to the sharp increase over the last 4 years.

The recent rapid growth of the local market has been driven by four main factors:

- The plummeting global prices of PV
- Enabling policy, legal and regulatory frameworks.
- Government PV projects ï PV electrification of public institutions and facilities and hybridization of mini-grids
- Rising interest in grid-connected systems for self-consumption
- Off-grid World bank supported Lighting Africa programme.

The new energy policy commits to continue and enhance existing strategies to support the industry. The government projects are continuing and new PV programmes have been started such as the World Bank funded, $150 million, Kenya Solar Access Project. The interest in grid-connected producer-consumers (prosumers) is increasing as PV generated electricity becomes competitive with national grid power.

It is clear that the policy environment and market circumstances are in support of continued market growth. Consequently, the market has high growth prospects.

iii) Key players in the local market

The keys players in the Kenyan market are government institutions that oversight and regulate the sector, industry promoters and financiers, business enterprises and customers

The key government agencies are the Ministry of Energy (MoE), Energy Regulatory Commission (ERC), the Kenya Bureau of Standards (KEBS), Rural Electrification Authority and Kenya Power and Lighting Company Ltd (KPLC). Whereas the MoE formulates policies and identifies resources, ERC takes care of sector regulation both technical and economic covering all sub-sectors. KEBS develops and enforces standards and KPLC is the only electricity off taker.

The key industry promoters and financiers include bilateral and multilateral development agencies, NGOs, banking institutions and micro-finance institutions. These have been involved in financing PV projects, capacity building, promotion and awareness creation. They include the world bank group, both IDA and IFC and UN agencies such as UNICEF and UNDP, GEF, bilateral development partners such as UKAID, USAID, JICA, GIZ, etc., and international NGOs like Oxfam, SNV Netherlands, GVEP, etc.

The major business enterprises include Davis and Shirtliff, Sollatek Electronics, Chloride Exide, Powerpoint Systems, Power Options, GoSolar, DôLight and Greenlite Planet.

The major consumers of PV are private individuals and institutions, government agencies and NGOs and international development partners.

iv) PV Products in the market – Key components

PV Modules

All types and capacities of PV modules and balance of systems (BOS) components are available in the market.

Crystalline PV modules, both mono-crystalline and polycrystalline types dominate the market. They are available in a wide power range from 1W to 330W and at voltages 12, 24 and 48V DC nominal. The average price is KShs 98.44 per Watt

The major brands available in the market include Jinko, Yingli, Trina, Solinc. Amerisolar, and Kyocera.

Inverters

Both modified sinewave and pure sine wave types are available in the market but sinewave inverters are the most common in the market. There are a few grid-tie inverters in the market. The power rating of the inverters in the market range between 100W and 50kW. The common input DC voltage are 12V, 24V and 48V. The inverter prices vary between KShs 7 per watt to KShs 62 per watt. The average price is 22.50 KShs/W.

The common brands include Victron, SMA, Xantrex, MUST, Sukam, Sollatek and Schneider.

Charge Controllers

The two common types Maximum Power Point Tracking (MPPT) and Pulse Width Modulation (PWM) are available in the market and the prevalence is almost equal at 50%.

The nominal rated voltage of the charge controllers found in the market are 12V, 24V and 48V. Almost all of them are duo-voltage and can operate at both 12 and 24V. The current rating of the charge controllers in the market ranges between 5A and 80A. Charge Controller prices vary between KShs 200 per A to KShs 730 per Ampere. The average price is 423 KShs/A.

The common brands in the market include Morning Star, MUST, Outback, SMA, Sollatek, Victron and Steca.

Solar batteries

Both lead acid and alkaline batteries are available in the market but lead acid dominates with a prevalence rate of 95%. The packaging of the batteries is either vented or sealed and sealed type may be gel or flooded. The sealed battery dominates the market at 89% prevalence rate.

The batteries are available in 2V, 6V, 12V and 24V modules. The battery capacities range between 7AH and 4700AH. The 100 and 200AH batteries dominate the market. The average price is 150 KShs/AH.
The common brands include Ritar, Chloride Exide, Champion, Gaston, Sollatek, Sukam, and Dayliff.

Load Appliances

Lighting and water pumping are key applications of PV in Kenya and the survey sought to find out what lamps and pumps exist in the local market. Others include TVs, Refrigerators and Air Conditioners.

There are several brands and types of DC lamps in the market. They include Lumia, Sollatek, Topolo, Sunking, Sundaya. They are available in LED, Fluorescent and Compact Fluorescent versions. The wattage varies between 6W and 18W. Most operate on 12V DC. Prices range between KShs 600 and KShs 800 per lamp.

Energy efficient solar pumps reduce the size and cost of PV pumping systems. The common brands include Grundfos, Lorentz and Shurflo.

v) PV Products in the market – PV systems

There are packaged systems and custom-designed PV systems.

Packaged systems

The integrated packages include solar lanterns and plug- and-play solar home systems (ISHS), which do not require special skills to operate. Solar Lanterns come with PV modules of between 1Wp and 5Wp, while ISHS come with PV modules of between 10 and 40 Wp.

The common brands available in the market include DôLight, Sunking, Solectric, Niwa, Barefoot, Uno and GD lite.

Solar lantern prices lie between KShs 500 and KShs 8000 per lamp. The average price is Kshs 3,300 per unit. The ISHS prices lie between KShs 1800 and KShs 30000 per system. The average system price is KShs 1130 per Wp. The average system capacity is 13 Wp.

Custom-designed systems

The customized systems available in the market include component based solar home systems (CSHS), stand-alone institutional power systems (SSPS), street/security lighting systems, solar pumping systems (SWP), min-grid and grid-connected systems. All these are designed to meet pre-determined power needs.

They donꞌt have specific brands and prices vary widely. The average prices for systems of the common local configurations are shown in Table 1.

Table 1: Average prices of common PV systems configurations

Description	**Price (KShs/Wp)**
ISHS	1130
CSHS	762
SSPS	360
Street light	876
Mini-grids (with battery storage)	740
Solar pumps (complete)	210
Solar Pumping (power system only)	150

The levelized costs of SHS and SWP were estimated. The prices obtained are provided in Table 2.

Table 2: Levelized cost of PV generated electricity

Description	**Levelized cost (KShs/kWh)**
SHS	146
Solar Pumping (power system only)	23

vi) Installed capacities

A rough estimate of the installed systems capacities was worked out using capacities of known operating installations for customized systems, data from a few business enterprises, sales of solar lanterns and kits from lighting Africa Programme, number of households using solar from Kenya Integrated Household Budget Survey (KIHBS) of 2016 and general knowledge of the market.

An estimate of the installed capacity is 80 MWp as at year 2017. The rough breakdown of the above is provided in the Table 3.

Table 3: Estimated installed PV capacities in Kenya

Description	**Installed capacity (MWp)**
SHS and lanterns	30
SSPS	20
Solar Pumping	20
Street lighting	1
Mini-grids	1.3
Grid connect	6
Total	**77.6**

vii) PV systems performance

End-users and suppliers of PV systems and services were interviewed to determine the performance of PV systems. 64% of suppliers and end-users stated that the performance of PV systems is good and 27% state that the performance is satisfactory. Both users and suppliers agreed that the solar panel was the most reliable component of the PV systems. The battery was the most unreliable and causes most failures followed by the Inverter. The charge controller is the most reliable BOS component of PV systems and lack of maintenance was cited as one major cause of poor systems performance.

The above is a clear endorsement of PV as an electrical energy alternative source for the country. Lack of maintenance and battery problems were the main causes of poor performance. These should be targeted for corrective actions.

viii) Challenges in the adoption of solar PV in Kenya

Stakeholders identified the main challenges and barriers faced by the industry to be taxation, high cost of PV, consumer awareness, financing, policy and regulation, lack of enforcement of standards and regulations and skills availability and adequacy.

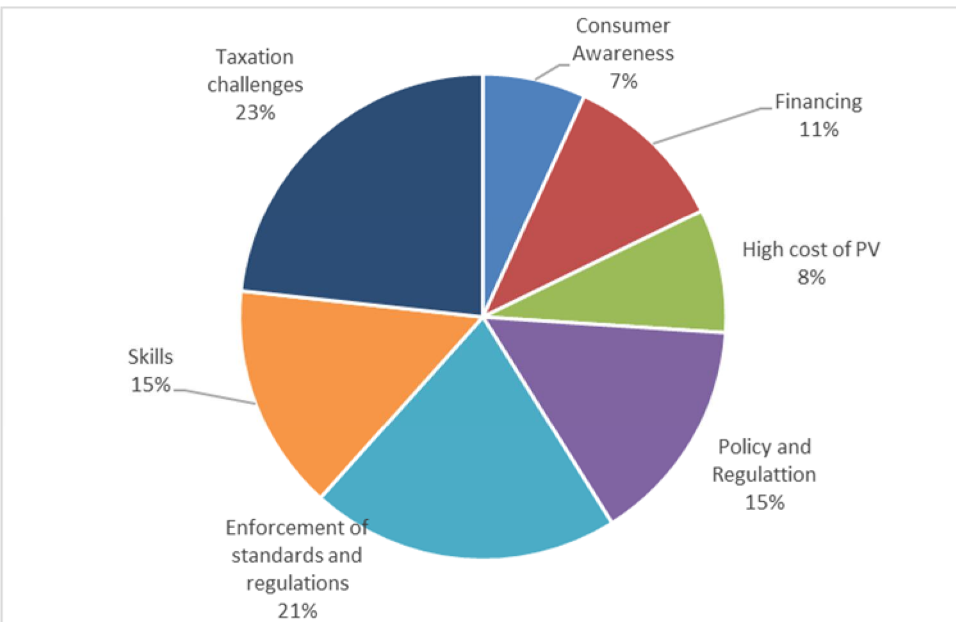

Figure 3: Frequency of challenges and barriers hindering PV adoption in Kenya

It is observed that taxation and enforcement of standards are the biggest challenges followed by lack of adequate skills. Financing and consumer awareness challenges are still significant just as is awareness creation amongst consumers.

Government agencies are responsible for policy, taxation and enforcement of standards, which combined formed 59% of the challenges pointed out by the industry. It is therefore clear that government action is the one single stakeholder whose intervention can rapidly transform the PV industry in Kenya.

ix) Skills gaps in the industry

Skills availability and adequacy were assessed. PV business and technical skills were grouped into five broad categories and businesses were asked to indicate the whether the skills are available in the industry and whether they are adequate. Skill adequacy means that the sector has enough supply of trained and competent personnel to provide professional PV services.

The main finding was that skills at all levels are available to a great extent. However, they are not adequate meaning that the industry does not have enough supply of trained and competent personnel to provide professional PV business and technical services to the market. There is lack of adequate and competent PV personnel to service the industry across the value chain for all PV system types including large SHS, hybrids, grid-connect and engineer, procure and construct (EPC) projects. It was also felt that there are inadequate skills in government agencies to professionally tackle policy and regulatory issues.

x) Policies and Regulatory gaps and recommendations

An analysis of the existing and proposed energy policies and strategies was undertaken.

The 2004 energy policy did not have a specific policy on solar PV technology. Instead it was lumped together with other technologies under óother renewable energy technologies. The new energy policy (2017) has specific sections devoted to solar energy and PV in particular. This is a positive development.

Under the 2004 policy now coming to an end, initiatives such as Feed-in-tariff, grants to public institutions for PV installations and direct funding for grid-connect and mini-grid systems and tax exemption on PV modules were implemented. Standards, codes of practice and PV regulations were introduced. Standardized training and certification schemes were also introduced.

The new policy aims to continue implementing policies and programmes that were initiated under the outgoing policy and at the same time address a number of challenges encountered by the industry during the implementation of the outgoing policy.

A look at the policies and strategies for rapidly growing PV markets shows that feed-in-tariffs, subsidies and taxation have been very successful market development support mechanisms. The new policy does not mention any form of subsidies or fiscal and financial incentives. The policy sets no targets for PV generation.

The general conclusion about the new policy is that it is broad, vague and short on specifics on solar PV. Whereas this is not necessarily bad because it gives room for wide interpretation and application, it creates room for doing very little especially where there are resource constraints and lack of creativity or interest on the part of the implementers.

The identified major shortcomings of the policy and regulations and recommendations are summarized below:

a) Review of the feed-in tariffs scheme

The feed-in Tariffs scheme does not cater for emerging market segments and approaches. Prosumers are not covered, tariff is flat, capacity limit unclear, standard PPA unsuitable for some segments, etc. The feed-in tariff policy should be reviewed to address above and other challenges and to accommodate new developments in the PV market.

b) Review and clarify taxes on PV BOS components and PV generated electricity

There is also lack of clarity on application as the interpretation differs between agencies. It is recommended that this sticking issue be reviewed with a view to making it clear so that all agencies understand what taxes to levy on what products and services.

c) Financing and Investment support for PV

The new policy has avoided the issue of financing altogether save for the grants to public institutions. There are various financing models that have been used to support PV markets. The most common are grants and subsidies, equity, debt and asset financing models. It is recommended that the government develops PV specific financing and investment support schemes with a view to facilitating the private sector and PV consumers to invest in PV systems.

d) Set PV capacity targets

One major drawback of the policy is lack of PV capacity targets to be achieved within the policy timeframe. Without targets in the policy, the industry can not undertake effective long-term investment planning, more so for private investors. PV targets should be set and by regions. It is recommended that clear capacity targets by geographical regions be set in addition to the national target.

e) Develop SHS and Stand-alone incentive schemes

The current tariff is beneficial to investments aimed at grid-connection only. The policy has ignored solar Lanterns, Plug and Play SHS, Stand-Alone PV, street lights and solar pumping. Yet these would have greatest national impact.

It is recommended that incentive schemes targeted at stand-alone PV systems be developed

f) Review administrative and regulatory processes and procedures for the PV sector.

Even though some guidelines were prepared together with the introduction of feed-in tariffs, it is felt that they are in-adequate to cater for the emerging market segments and approaches to the identification of projects. For example, energy auctions have been mentioned to replace existing un-competitive investor led processes.

To avoid such situations, administrative and regulatory processes should be reviewed to address challenges identified earlier and introduce new and efficient approaches for project identification all the way to approval and implementation covering all market segments.

g) Enforce existing regulations and standards

The industry has identified poor enforcement of standards and regulations already in place as one major setback for the industry. The consequence of this state of affairs has been proliferation of counterfeit products, poor and non-performing PV installations and entry of substandard PV products and services into the market. Efforts should be redoubled to ensure effective enforcement of existing standards and regulations.

h) Timely implementation of policies and strategies

Good policies are of no use if they are not implemented. But experience has shown that Kenya is very good at making policies but poor at implementing them. This is the only reason we are emphasising that timely implementation should be the ERC mantra.

1. INTRODUCTION

1.1 Background

The Energy Regulatory Commission (ERC) is the single energy sector regulator, with responsibility for economic and technical regulation of electric power, renewable energy, and downstream petroleum sub-sectors, including tariff setting and review, licensing, enforcement, dispute settlement and approval of power purchase and network service contracts.

The commission is mandated to, among others: -

i) Regulate the importation, production, distribution, supply and use of renewable and other forms of energy;
ii) Protect the interests of consumers, investors and other stakeholders.
iii) Monitor, ensure implementation of, and the observance of the principles of fair competition in the energy sector, in coordination with other statutory authorities;
iv) Provide such information and statistics to the Minister as he may from time to time require;
v) Collect and maintain energy data;
vi) Prepare indicative national energy plan;
vii) Perform any other function that is incidental or consequential to its functions under the Energy Act or any other written law.

ERC is mandated to collect and maintain energy sector data. Furthermore, energy sector data and information is crucial in the formulation of appropriate policies and regulations that would better protect the interests of all industry stakeholders.

ERC has not undertaken any PV industry study in Kenya. Yet, according to the latest Kenya Integrated Household Budget Survey (KIHBS) of 2015/2016, 14.1 % of households in Kenya use PV for lighting. This means that PV contributes significantly to the countryǿs household fuel mix.

To execute its mandate of data collection and maintenance, ERC engaged Rencon Associates Ltd, a Renewable Energy and Energy Efficiency Consultancy Firm to undertake a study of solar PV industry market in Kenya.

The study commenced in April 2018.

This is the Draft Final Report.

1.2 Objectives of the Study

The overall objective of the study was to assess the current status of the solar photovoltaic industry in Kenya, establish quality, capacity and performance of installed systems, identify barriers and regulatory gaps that hinder the growth of the industry and recommend measures to enhance the uptake of the technologies in the country.
The specific objectives were:

i) To identify the key players and products in the Kenyan Solar PV industry;

ii) To determine the capacity of the solar PV systems installed in the country;
iii) To assess the performance of systems installed in the country and identify the key reasons of success/failure of installed systems;
iv) To identify the trends in the development of the solar PV technology locally and globally including financing models and other policy instruments adopted to promote the uptake of PV products;
v) Model the levelized cost of PV generated energy (LCOE) for solar home systems and solar water pumping;
vi) Identify challenges in the adoption of solar PV in Kenya;
vii) Identify justified skill requirements for developing the solar photovoltaic industry in Kenya;
viii) Identify any regulatory/policy gap in the development of the Solar PV technology market in Kenya;
ix) Prepare a policy brief on the status of the Solar PV industry in the country and future prospects.

1.3 Organisation of the Report

This report comprises 10 chapters. The project background and objectives are presented in chapter 1. The methodology employed is presented in chapter 2. The results of the study are provided in chapters 3 to 10

2. METHODOLOGY

2.1 Methodology

The assignment was executed through desk and field studies.

The desk study was carried out to determine the trends in the development of the solar PV technology, international markets, policy and regulatory practices in other jurisdictions, financing options and general global market situation.

The field study was carried out to assess determine products in the market and their characteristics, capacity and performance of installed systems, to identify barriers and regulatory gaps that hinder the growth of the industry and related technical and market data and information

Based on the description of requirements in the terms of reference and the study objectives, the scope of work was divided broadly into four main tasks. These were:

Task 1	Kick of meeting and inception activities
Task 2	Data collection
Task 3	Data analysis and interpretation
Task 4	Reports preparation

The methodology employed in undertaking each of the above tasks to deliver on the objectives is described hereunder.

Task 1 Kick-off meeting and inception activities

The inception activities were preparatory and aimed at establishing work relationships, definition of data and information requirements and sources, preparation of final work plan and data gathering instruments. The project execution methodology was also finalized at this stage.

This activity began with a kick-off meeting which was held on 12th April 2018 at Energy Regulatory Commission Head Office, Eagle Africa Centre, Nairobi. At this meeting the draft contract, scope of work, deliverables, timelines and payments were discussed and agreed upon. The data, information and support to be provided by ERC were also reviewed and agreed upon. Matters to do with contract management, communication channels, reporting, etc. were clarified

The inception activities also involved preparation of interview questionnaires, refinement of the methodology, introduction letters to relevant agencies, and any other necessary preparations.

The inception activities took four weeks and resulted in the preparation and submission to ERC of the Inception Report.

Task 2 Data collection

The data requirements and methodologies employed for its acquisition aimed at meeting specific objectives are described hereunder.

i) Determination of the key players and products in the Kenyan Solar PV industry

The Energy Regulatory Commission has been regulating the sector since 2006, especially after the enactment of the solar PV regulations in 2012. All legally operating market players should therefore be licensed by the Commission and should exist in ERC databases. The ERC was therefore the first to be requested to provide a list of key players registered with them.

There are other key stakeholders who are not necessarily licensed or registered with ERC. These includes development partners (e.g. UNDP, GIZ etc), other government departments (e.g. KEBS, Ministry of Energy, REA, KRA), the industry association (KEREA) and NGOs such as (Practical Action, GVEP etc.) who are active in the local and international markets. These were contacted for references to obtain any other key players in the local and international markets that were not included in the ERC database.

To identify the products in the market, a combination of desk studies and field survey was used. The desk research involved looking for and reviewing any literature available about products available in the local and international PV markets, importation data from KRA. Product catalogues, internet searches and market studies were used to identify PV products in the market. The field research involved a market survey focused on major importers, manufacturers and distributors and retailers in 2 major cities in Kenya ï Nairobi and Mombasa using physical observations and face-to-face interviews with business enterprises.

ii) Global Solar PV Technology review and assessment

The objective of this review was to identify major manufacturers of PV components and equipment, status of the technology including battery storage and development trends, installed capacities, best practices for development of the technology including policy and financing models to promote uptake of the technology and related aspects of the technology and its applications

Data for this investigation was obtained from existing literature acquired from various sources including online sources, previous studies, public and private institutions that include international donor and development assistant institutions such as the World Bank (WB), International Energy Agency (IEA),International Renewable Energy Agency (IRENA) International Technology Roadmap for Photovoltaic (ITRPV) reports and similar organizations that have tracked the developments in the Solar PV sector and renewable energy globally over the past decades. PV technology and status publications were also be sought from European Joint Research Centre, Fraunhofer Institute, solar media, manufacturers and industry associations.

Governments and Government institutions regionally and international are usually mandated to establish and implement policy, legal, regulatory frameworks. Relevant documents shall be sought from regional and selected countries with similar economies to Kenya and also developed countries for review.

*iii)	Determination of the capacity of the solar PV systems installed in the country in the different categories*

Having identified the major players and the products available in the market, the products were categorized into market segments:

- Packaged products ï these are off-the shelf consumer products that do not need any installation such as lantern and solar home system kits
- Commercial products ï these will include systems that require installation by a technician and will be broken down into specific categories namely solar PV systems, solar mini-grids, solar street lights, and solar pumping systems

Using a structured questionnaire to capture relevant data about the said products, a field survey amongst the companies identified was undertaken. The questionnaire was designed in a manner to capture when the system was installed, the installer, the financier and whether private or government, the capacity of the installed system, the total cost and any other relevant information. Besides dealers and retailers field survey, importation statistics of PV devices, components and systems was gathered from KRA. These were used to corroborate and validate the field survey data in terms of totals for packaged products and capacities for PV panels and balance of system components.

According to PV regulations 2012, vendors and technicians are required to keep and/or furnish ERC with records of annual sales in terms of capacity (power) and systems installed. Sales reports submitted to ERC would have been a good source of this data but it was established that the reporting to ERC is very poor.

REA and Ministry of Energy have been installing PV systems in public institutions for over 10 years now. They were contacted to provide data as well.

Local PV studies and reports were also sought for review to support any findings obtained using the approaches above.

iv) Assessment of the performance of systems installed in the country and identification of key reasons of success/failure.

During the data gathering exercise described in ii) above, companies that engaged in installations were asked to indicate, if they are aware, whether the installed systems are operating or not. This was to generate a list of systems and the initial indication of the performance of the systems.

It is however unlikely that most companies follow up on systems once they have been installed to monitor their performance but they receive customer complaints when systems do not work well and attend to them. This can form a good basis for confirming systems performance. During the interviews, the businesses were asked about the common complaints and failure analysis to determine causes of poor systems performance.

Lastly, an end-user internet survey was carried out on a sample of mainly institutional end-users. Specific questions testing the systems performance over time was sent to end-users by electronic mail. End-users were requested to complete an attached simplified questionnaire and send the completed questionnaire back to the consultant. 50 institutions spread over 5 counties formed the sample. The counties were selected from geographical regions ï coastal region (Kilifi), central/Rift region (Kajiado), Western/Nyanza (Homabay), Eastern (Kitui), North Eastern (Wajir).

The data collected through the above methods was analysed to establish the performance of PV systems in the field.

vi) Determination of the levelized cost of PV generated energy (LCOE) for solar home systems and solar water pumping

Levelized Cost of Energy (LCOE, also called Levelized Energy Cost or LEC) is the cost of generating energy (usually electricity) for a particular system. It is an economic assessment of the cost of energy generating system including all costs over its lifetime and takes into consideration the initial investment, operational and maintenance costs, fuel cost and the cost of capital. LCOE is the minimum price at which the energy must be sold for an energy project to break even.

During the interviews, capital costs and operation and maintenance costs, equipment replacement costs, of PV systems were obtained from dealers. Data and assumptions on applicable discount rates, costs, analysis period, capacity factors, etc. were determined from the market and industry knowledge. LCOE was calculated using standard formulae.

vi) Determination of challenges in the adoption and deployment of solar PV in Kenya including any policy, legal and regulatory frameworks and gaps.

Solar PV has been in use in Kenya for over 40 years. Various challenges have been encountered along the long journey ranging from taxation, lack of skills, poor quality products and services, policies, financing etc. Some have been dealt with adequately such as taxation of PV modules and some may still be hindering the growth of the sector.

Some studies have been carried out that have identified some of these challenges. KEREA, the industry association will no doubt have on record some of the issues that dog the industry growth. Other stakeholders identified under ii) above would also be in a position to state the challenges they face in the market.

Three approaches were used to identify the challenges the industry is facing. Firstly, studies on PV were sought from various sources (Government, KEREA, etc.) for review. Secondly, face-to-face interviews with stakeholders was carried out focusing on challenges faced. Thirdly Kenyaœ policy, legal and regulatory frameworks were reviewed and contrasted with other countries especially where PV industries have been great success.

vii) Determination of skill requirements for developing the solar photovoltaic industry in Kenya.

PV requires skills across the value chain. With most components being imported then skills are required mostly in marketing, sales and logistics and engineering i.e. design, installation, testing and commissioning, operations and maintenance. Other areas are more of support e.g. finance, accounts etc.

Many PV capacity building activities and training courses have been undertaken in Kenya. It is however not known the extent to which the skill gaps that were prevalent in the past have been filled. This question is best answered by industry players themselves especially companies, technicians and other stakeholders who are directly involved with the sector.

Two methods were employed to identify the skills gaps. The first was through a review of available literature and studies. The second was through a field survey carried out on a sample of stakeholders including KEREA, major distributors and installers. Other players involved in PV promotion and projects such as development agencies and NGOs were also interviewed. Some end-users with large PV systems such as Strathmore University were also interviewed.

ix) Preparation of a policy brief on the status of the Solar PV industry in the country and future prospects.

The data acquired was analysed and interpreted and the results were used for preparing a policy brief on the status of PV industry in Kenya and future prospects.

x) Sample size

There are many business enterprises active in the PV industry in Kenya. However, only about 20 of these companies are considered to have significant market share and the consultant estimates they control over 80% of the market. In all, it was intended to interview 10 business enterprises but and many more were eventually interviewed after undertaking background searches and information about the industry plays. Those interviewed included

- Davis and Shirtlif
- Chloride Exide
- Power Point systems
- Go Solar
- Power Options
- Sollatek

Besides businesses, other key stakeholders include Government agencies, NGOs and International Development agencies. These have played various roles in the promotion of the development of the industry and have good grasp of the local PV industry. Those interviewed included:

- Lighting Africa programme of World Bank
- SNV of Netherlands
- GIZ of Germany
- KEREA- the industry association
- Ministry of Energy
- Rural Electrification Agency

An end-user internet survey was carried out on a sample of mainly institutional end-users from public institutions. 50 were targeted but 29 responded to the survey. Lastly all counties were interviewed on telephone on the use of solar street lights. 31 counties responded positively.

Overall, over 100 stakeholders participated in the survey.

The list of companies, informants and end-users who were interviewed is provided in Annex 3.

xi) Data gathering tools

Field data was gathered through interviews with stakeholders identified in the preceding section.

Interview questionnaires that were guiding the consultantôs engineers/researchers in face-to-face interviews with the relevant personnel were used to gather data and information as appropriate. The questionnaires were tailormade to the targeted interviewee based on the data and information being sought. The questionnaire is attached to this report as Annex 1.

TASK 3 Data Analysis and Interpretation

The data and information collected was processed through editing, validation and tabulation to make it suitable for analysis. Editing was done to correct errors to ensure that data is accurate, uniformly entered and consistent with other facts gathered.

Qualitative and quantitative analysis methods were then used to analyse the gathered data. Statistical methods including averages, simple regression, correlation analysis and normal distribution patterns were used for the analysis of quantitative data such as installed capacities, trends, indices, etc. Qualitative methods were used to analyse non-quantitative data such as policies, regulations and their impacts, etc.

The data analysis results were then interpreted to provide the requisite data and information:

a) List of international manufacturers, products, technological developments and trends, devices and equipment performance, installed capacities in selected jurisdictions, policy instruments and financing models including successes and failures, policy briefs.
b) List of key players in the market
c) List of products available in the market (Panels, lanterns, batteries etc), country of origin, frequency of the products, perceived quality, etc.
d) The installed systems data gathered under task 3 (ii) was grouped according to market segments and installed capacities estimated.
e) The systems performances were grouped into three categories ï Good, satisfactory and poor. The causes of failure were also evaluated. This was used to get an indication of the state of operation of systems in general and the reasons for poor performance.

f) The levelized cost of energy was computed from the equation:

$$LCOE = \frac{\text{Overnight Cost of Capital} * \text{Capital Recovery Factor} + \text{Fixed O\&M}}{8760 * \text{Capacity Factor}} + (Fuel\ Cost * heat\ Rate) + Variable\ O\&M$$

Where:

i. Overnight cost of capital = $/kW

ii. Capital Recovery Factor CRF is computed from:

$$CRF = \frac{\{i(1+i)^n\}}{\{(1+i)^n)-1\}}$$

iii. Fixed O&M =Dollars per kilowatt-year $/kW-year

iv. Variable O&M = Dollars per kilowatt-hours $/kWh

v. 8760 ï Number of hours per year

vi. Fuel Cost (Where applicable) ï for PV this value is Zero.

vii. *i* is the discount rate and *n* is the useful service life of the PV generator

Task 4 Reports Preparation

The writing of the study reports was the final task in the assignment. The following reports are be prepared in the course of the assignment.

- Inception Report ï done in May 2018
- Draft Report - this report
- Final Report

In between the above key reports, consultant was providing a monthly progress report outlining activities undertaken and planned activities for the following month and outlining any challenges encountered and how they have/or were being resolved to minimize any impact on project.

2.2 Challenges encountered

i) Business enterprises were not keen to provide internal financial and installed systems capacities data. Financial and sales volumes data was particularly difficult to get and only two companies provide credible data. Data on installed systems and capacities was almost non-existent. Most of the submitted completed questionnaires did not have any sales and installed systems data.

ii) Interviewees took too long to provide data despite frequent reminders including repeated visits

iii) Wajir County internet interviewees did not respond to our systems performance questionnaire

iv) Importation statistics data from KRA has solar products mixed up with other products in Harmonized System (HS) codes. Consequently, it is difficult to determine type, quantities and value of solar equipment entering the country.

3. REVIEW OF PHOTOVOLTAICS TECHNOLOGIES AND BALANCE OF SYSTEMS COMPONENTS

3.1 PV Technologies

The solar Photovoltaic Technology (PV) utilises the sunôs energy, specifically sunlight to generate electricity using properties of semiconductor materials that have been specially treated in high tech processes. Solar PV systems use the Photovoltaic effect to generate Direct Current (DC) electricity that can be used directly to operate DC appliances and equipment or can be converted into grid-quality Alternating Current (AC) for operating conventional AC equipment, appliances and systems or can be fed into the grid system, for distribution and utilization like the conventional power.

In 1839, a Frenchman called Berkerel discovered that when some materials are exposed to sunlight, they exhibited some electric generator effect ï the photovoltaic effect. These materials are called semi-conductors. With time, these semiconductor materials were investigated, then purified and specially treated resulting in the first commercial solar module being produced in 1958. Due to the lack of appropriate and cost-effective production technologies, solar systems were expensive and were used in powering spacecrafts in the sixties but were very expensive for terrestrial applications.

Major breakthroughs in cell and module production in the 70ôs, the discovery of new manufacturing techniques in the 80ôs, (fuelled by the middle east oil crisis) resulted in substantive cost reduction in the production of solar modules. Economies of scale as the production increased in response to market demand resulted in a growing global market. Commercialisation of the technologies became possible in the 1970ôs when major breakthroughs were made in production of silicon cells. In the 1980ôs and 1990ôs new and lower cost production methods were established. Since then continuous improvements in manufacturing processes and material utilisation and entry of other players especially from Asia and economies of scale driven by increasing market demand have resulted in fast declining prices making PV power generation more competitive with conventional power generation.

PV technologies can broadly be grouped into two ï crystalline and thin film technologies.

There are two proven and predominant crystalline PV technologies, both based on Silicon solar cells. These are the mono-crystalline (Mono-Si) and multi-crystalline silicon (Multi-Si) PV technologies. Mono-Si solar cells are sliced from single-crystal boules of grown silicon. These wafers/cells are cut as thin as 160 microns. Multi-Si solar cells are sliced from blocks of cast silicon and they are less expensive to manufacture but also less efficient than Mono-si.

The proven and commercialized thin film technologies are Amorphous Silicon (a-Si), Cadmium Telluride (CdTe), Gallium Arsenide (GaAs) and Copper Indium Gallium Diselenide (CIGS).

Multi-junction technologies, utilizing both crystalline and thin-film, are being developed but have not yet been commercialized in any significant way. They basically have two, three or four P-N junctions made from different semi-conductor materials instead of the single junction thus enhancing the conversion efficiencies by capturing the wider spectrum of light, such as the infrared energy, falling and entering the solar cell that the normal solar cell does not respond to, and also reducing transmission and reflection losses.

Lastly there are concentrator systems that use advanced optics such as reflectors to focus sunlight onto the solar cells or modules. Lenses, with concentration ratios of 10x to 500x, typically Fresnel linear-focus or point-focus lenses, are most often made of an inexpensive plastic material engineered with refracting features that direct the sunlight onto a small or narrow area of cells.

There are emerging PV technologies like perovskite and organic cells (polymer or plastic) that are in early development stages but laboratory results are promising and have potential for lowering production costs.

The power output performance of the PV technologies is of crucial importance to power producers and the key parameter that is used to determines this is the solar cell and module efficiency. The reported confirmed [1] efficiencies of solar cells and modules produced using the above technologies are provided in Table 3.1.

Table 3.1: Reported best efficiencies of solar cells and modules of by technology

PV Technology	Module Efficiency (%)	Best Research efficiency (%)
Mono-Si	24.4	26.7
Multi-Si	19.9	22.3
A-Si	12.3	14
CdTe	18.6	21
CIGS	15.7	22.9
GaAs	24.1	28.8
Multi-Junction/ Concentrator	38.9	46

Solar cell efficiencies have not always been good. It is advances in semiconductors materials purification and processing and development of new cells and modules production methods that have contributed to this impressive efficiency gains over the last 40 years. Figure 3.1 , extracted from Fraunhofer PV report [2] illustrates the efficiency improvement trends over the last 25 years.

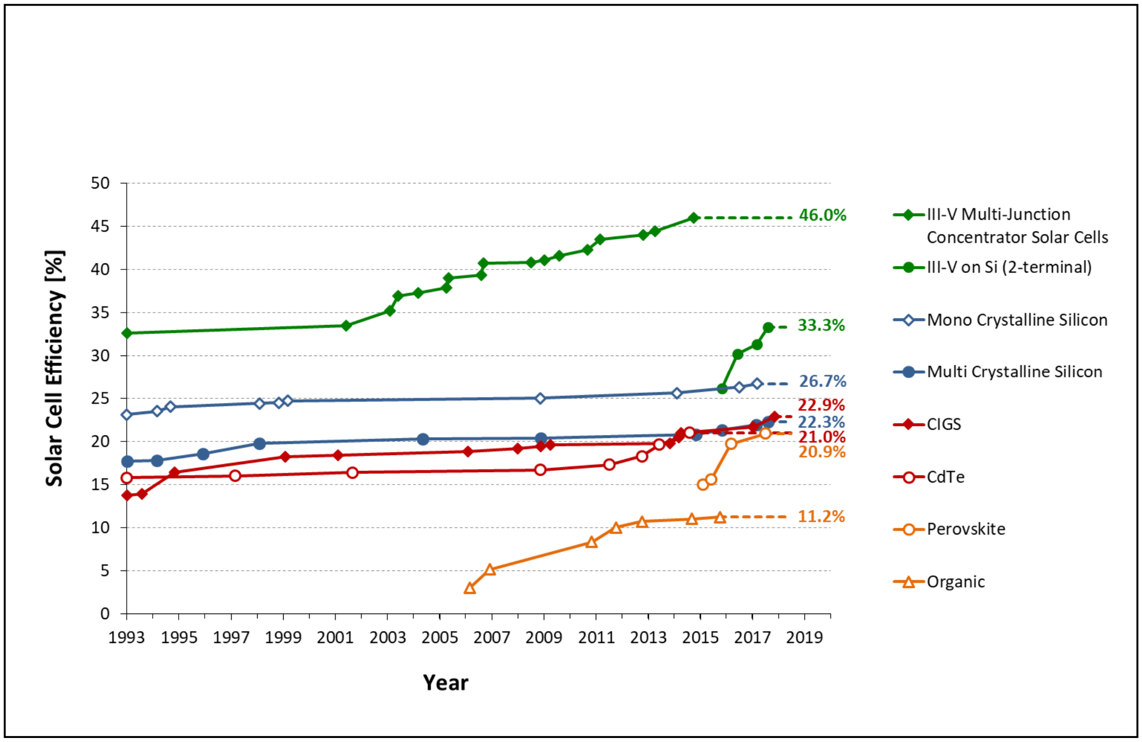

Figure 3.1: Solar cells efficiency improvement trends.

Production processes, material utilization and power output stability and of course the price are the other determinants of the effectiveness and market success of a technology.

Thin film technologies utilize less materials and the processes they undergo to produce solar cells and modules are less complex and cheaper hence they generally result in cheaper PV modules. Amorphous silicon is the cheapest thin film technology but suffers serious instability, despite efforts to stabilize it, resulting in high power output degradation. This in addition to its low conversation efficiency has seen it lose ground to CdTe and CIGS which have higher efficiencies and are better at sustaining power output. GaAs solar cells are quite expensive but are good for multi-junction and concentrator systems because of their high efficiency and higher operating temperatures. They are mostly used in special applications like in powering spacecrafts.

The crystalline silicon technology has dominated the PV industry because of its high efficiency, abundance of the main raw material (Silicon), existing and developed silicon production and processing industry, and growing demand.

Due to the improvements in production processes and material utilization and economies of scale the price of crystalline silicon technology has declined exponentially over time. Figure 3.2 illustrates the price trend over 40 years.

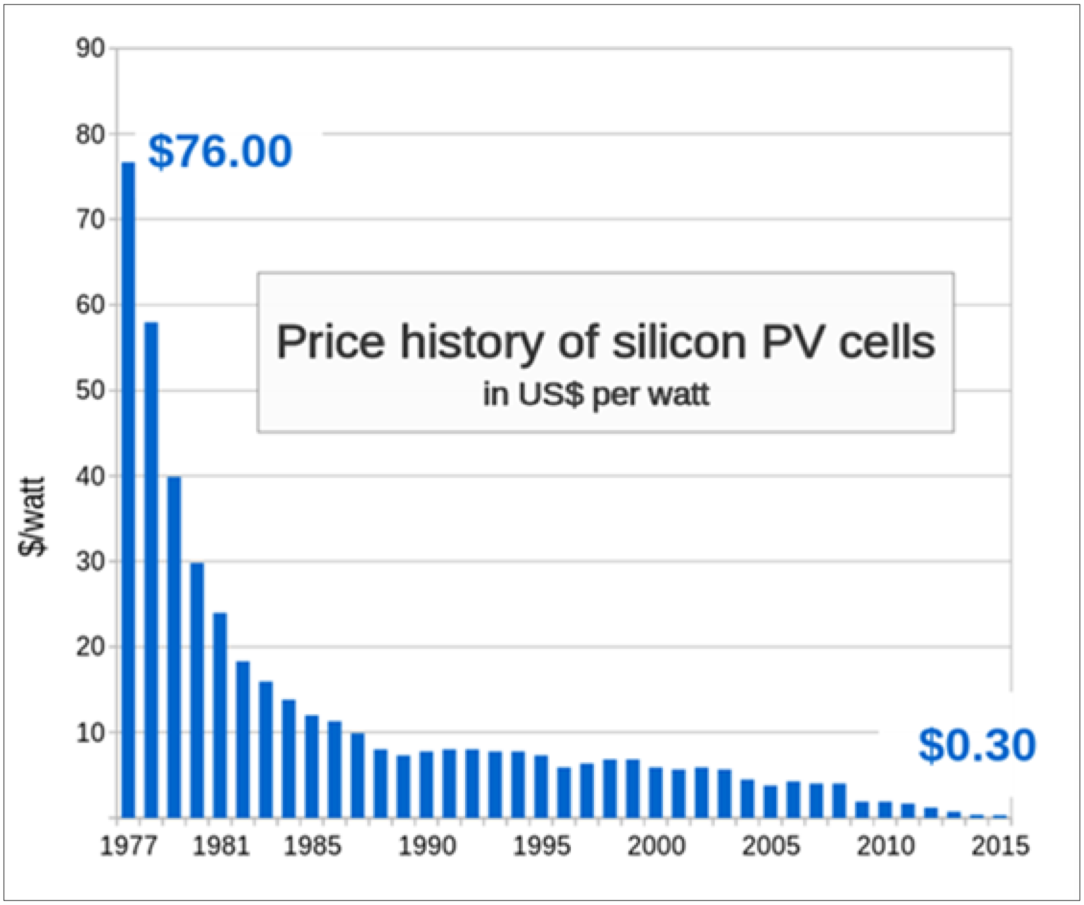

Figure 3.2: Price trend of crystalline solar cells over 40 years.
Source: Bloomberg New Energy Finance and PV Energytrend,com

3.2 Balance of Systems Equipment

PV generated electricity is Direct Current but most equipment and systems are designed to operate on Alternating Current (AC). An Inverter is therefore a critical component in PV power systems. PV is only available when the sun shines but it is desirable to make it available whenever it is required especially in developing countries where access to the electricity grid is minimal and its used for lighting at night. Electricity storage batteries are therefore a necessity. With batteries in the PV system, there is a need for battery charging and usage control which is accomplished with a charge controller. The three PV systems component, the battery, Inverter and charge controller are the key PV components generally referred to as the Balance of System (BOS) equipment.

A review of the PV technology would be incomplete without a mention of these three components and they are briefly described hereunder.

3.2.1 Inverter

Inverters convert DC power generated by PV to AC power to make it suitable for conventional grid style manipulation and utilization for home and industry.

An Inverter is a sophisticated electronic device that uses switching transistors for converting and reversing the output polarity 50 or 60 times per second after which the low voltage AC output is passed through a transformer to produce the required AC power at appropriate voltages usually 220/230 V AC single phase or 430 V AC three phase.

There are three basic types of Inverters - square wave, modified square wave and sine wave, referred to as pure sine wave. The names are derived from the shape of the wave that the AC they produce makes as its voltage rises and falls with time.

The need for AC power on the advent of PV technologies has seen the Inverter technologies developed from mechanical low efficiency types to the current, solid state high efficiency types.

The key factors to consider when choosing an Inverter besides its capacity (power rating and surge ability) for the expected load are its efficiency, power quality (mainly waveform, harmonic distortions) and availability and of course the prices.

A lot of progress has been made towards improvement in performance of Inverters mainly driven by improved power semiconductors changes in designs and configurations. As a result, costs have declined from 1.15 $/W in 1990 to almost 0.0.12 $/W 2014 [2].

Sinewave inverters have always been expensive compared to the other types, costing almost three times the modified sine wave types. Just over 10 years ago, the dominant inverter type for off-grid applications was the modified sine wave.

Technological improvements and economies of scale have seen the sine wave inverter prices decline to a level where they currently dominate the off-grid market, even here in Kenya.

3.2.2 Solar Batteries

Most PV systems require batteries to store electricity generated during the day for use whenever it is required particularly at night and during periods of poor sunshine. Batteries store the energy in a chemical form while charging and when in use, the chemical energy is converted into electrical energy.

All types of batteries have been used for energy storage in solar PV systems. However not all of them are suitable for use in PV systems because different battery types are designed bearing in mind the characteristics of applications it is meant to serve. The differences in application, source and characteristics of the recharging power, the need for low maintenance and long service life makes the design and manufacture of solar batteries different from the other battery types.

Several battery technologies exist. Some have been in existence for ages while others have recently been developed while others are under development.

Lead Acid batteries

Lead acid batteries have been in existence since 1859. Lead and lead dioxide are the negative and positive plates/electrodes respectively with Sulphuric Acid being the electrolyte.

Lead acid batteries can be made with flat plates or tubular plates. They can be packaged to use liquid acid (flooded) or immobilized acid (sealed) in form of a gel. They can be made in various capacities and voltages.

In terms of performance, lead acid batteries are relatively efficient, with a round trip efficiency (RTE) of 70-90%, lifespan of 5 to 15 years, fair cycle life, reliable, readily available, and suitable for PV applications. With some design modifications and addition of some elements to the plates, cycle life and efficiency have been enhanced. The main disadvantages of lead acid batteries are the slow charge regime, low weight to energy ratio, low power and energy density, relatively short cycle life and high maintenance requirements.

Lead acid batteries provide a relatively low cost and acceptable form of energy storage. As a result, it dominates the PV industry at the moment.

The battery costs between $200 and $400 per kWh

Nickel Cadmium

Nickel Cadmium (NiCad) batteries have also been in existence since for a very long time. Nickel Hydroxide and Cadmium hydroxides are the positive and negative plates/electrodes respectively with potassium hydroxide being the electrolyte. Other electrodes that have been used with Nickel as electrodes include Iron (NIFE), Zinc (NiZn) and hydrogen (Ni-H) and electrolytes are not always potassium but even Sodium Hydroxide has been used

In terms of performance, NiCad batteries are very good. The have reasonably high power and energy densities, very good cycle life, long service life of about 20 years, fairly high RTE, highly reliable and quick charging times and very suitable for PV applications. The main disadvantages of NiCad batteries are the high cost, not readily available and use of toxic materials. As a result, they are mostly used in consumer electronic where energy storage capacities are low.

They cost between $500 to $1500 per kWh.

Lithium-ion batteries

In lithium-ion battery technology, the positive electrode is graphitic Carbon, the negative electrode is lithium metal and the electrolyte is lithium salts dissolved in organic carbonates of lithium.

Lithium ion batteries have very high efficiency (RTE close to 100), high power and energy densities, high cycle life and long lifespan, and high voltages. Their main disadvantage is the high cost and as a result they are widely used in consumer electronics.

Li-ion technology is developed and in early stage of commercialization for large power storage as found in PV applications. They cost between $600 to $2500 per kWh.

Sodium- Sulphur batteries

The Sodium- Sulphur (NaS) batteries consist of molten Sulphur and as the anode and molten sodium as the cathode which are separated by solid alumina ceramic electrolyte which allows the sodium irons to flow through it to combine with Sulphur to produce sodium polysulphide during the charging process. This is a reversible process and the opposite occurs during discharge allowing electrons to flow in the external circuit to produce 2V.

The sodium and Sulphur electrodes have to be heated to remain in molten state and the battery packs are thermally insulated. The batteries have a high-energy density and high efficiency.

NaS batteries are in their early commercialization stage. They cost between $300 to $500 per kWh.

Flow batteries

In conventional batteries such as lithium-ion, leadï acid and Nicads, the energy storage capacity is limited by the amount of active materials contained within the battery cells. In flow batteries, the electrolytes are stored in separate external tanks. During charging or discharging, the electrolytes are pumped through permeable membranes allowing ions exchange to take place between the two electrolyte tanks. Three main types of flow batteries exist ï Zink-Bromine (Zn-Br), Vanadium redox flow (VRB) and polysulphide-bromide (PSB) batteries

Flow batteries are in their early development stage. They cost between $600 to $2500 per kWh.

In conclusion, the combination of performance, price and availability makes lead acid batteries the most suitable and predominant battery technology for off-grid PV applications. Nicads and Li-ion would be better but for price and availability. The other technologies are at various stages of development and commercialization.

3.2.3 Charge Controllers

A Charge Controller is an electronic unit that controls the charging and discharging of batteries to prevent battery damage that can result from the excesses of both. Although the key function of the Charge Controller is to protect the battery, some other control and supervisory functions have been incorporated into it. These include system monitoring and status indication, load management and system fault diagnostics. It is therefore a very important component of stand-alone and off-grid solar PV system. They are also used in mini-grid and grid-tied systems where a need for storage for back-up or demand management is required.

Charge Controllers incorporate a charging current control device and battery voltage monitoring and control electronics. The charging current control device is usually a transistor switch although mechanical relays have been used in the past. The control electronics monitor the battery voltage. When the battery voltage reaches a pre-set level, a control signal is produced that reduces or cuts off the charging current passing through the transistor. Similarly, when a battery voltage falls to unacceptably low level, a control signal is produced that cuts off power to the loads. This way battery damage due to over-discharge and over-discharge is avoided.

There are two main types of charge controllers, shunt and series. In shunt regulators, the control element is in parallel with the battery and charge regulation is achieved by diverting the charging current through another path. In series regulators, the control element is in series with the battery and charge regulation is achieved by reducing or cutting off the charging current from the PV modules once the battery voltage rises to a preset value. A hybrid type comprising the two control modes is also possible.

Best solar battery charging regime involves three main stages. The bulk charge is the first stage at which all current available from the solar panel is applied to the battery until the battery reaches the preset voltage. This is followed by the absorption or equalization stage at which just enough current is applied to the battery to hold a preset absorb voltage for a set period of time. This stage is designed to prevent overheating and over-gassing of the battery. The last stage is float mode at which maintenance charge is applied to the batteries until there is no more excess energy available - the end of a sunny day.

To enhance and optimize battery charging, charge controllers do most of the times incorporate pulse width modulation (PWM) and maximum power point tracking (MPPT). PWM kicks in after a battery attains a good state of charge (absorption charging stage) and ensures that the battery is slowly taken to a higher state of charge by injecting controlled pulses or bursts of energy. It also introduces controlled gassing which reduces electrolyte stratification. MPPT on the other hand tracks the maximum power available from solar panels and adjusts the charging set point to maximize the energy capture from the panels. MPPT controllers almost always incorporate PWM.

Series regulators have very precise charge regulation but tend to be less efficient than shunt regulators. On the other hand, shunt regulators tend to run hot which reduces their service life.

The solar charge controllersô technologies are standard electronics and it is the addition of performance and reliability enhancing features such as PWM, MPPT and supervisory, control, monitoring and load management functions that differentiates them. These additional functions also have a bearing on prices, with MPPT controllers being more expensive. MPPT are increasingly becoming the controllers of choice for large PV systems.

4. GLOBAL PHOTOVOLTAICS MARKET REVIEW

4.1 Demand and growth trends

Commercialization of PV became possible in the 1970ĝs when major breakthroughs were made in production of silicon cells, which substantially brought down the cost of producing solar modules. Even then, terrestrial application of the technology was only competitive for remote area applications where grid power was unavailable and delivery of petroleum fuels for power generation was difficult. As a result, the emerging market then was a professional applications market to provide power to installations in remote locations such as, telecommunications repeater sites, telemetry, cathodic protection, railway signaling and the like. This market was dominated by original equipment manufacturers (OEMs) and governments/government utilities/corporations. In the early 1980ĝs, PV for remote areas had become more competitive and Governments, NGOs operating in remote areas such as OXFAM and UN bodies such as UNICEF, created an additional market in which PV was being installed to operate medical refrigerators in remote health centres to replace Kerosine/Gas refrigerators and equipment and lighting in field offices. PV awareness and its benefits slowly set in and schools, health centres and individual households started adopting the technology mainly for lighting and low power applications.

At the time, the main players at the international scene were European, American and Japanese oil and electronics corporations such as Arco, BP, Helios, Sharp, Siemens, Solarex and Shell. These companies supported by their governments continued with research and innovation in materials, processes and techniques to raise solar cell efficiencies and reduce module production costs.

In the 1990ĝs new companies especially from Asia started getting interested in the PV market and slowly but surely ventured into the market. Driven by Government policies, regulations and incentives to promote the use of PV both in Asia, Europe and America, the demand for PV continued to rise rapidly and more investors entered the market. Most western companies shifted their manufacturing to Asia especially china. To date, China leads the world in production of PV modules.

Since then continuous improvements in manufacturing processes and material utilization, improving cell efficiencies and entry of other players especially from Asia and economies of scale driven by increasing market demand created by governments through policies and instruments to promote the use of PV have resulted in fast declining prices for PV and rapid market growth over the last 20 years.

Figures 4.1 illustrates the production, Installation (consumption) and production capacity growth trends over the years.

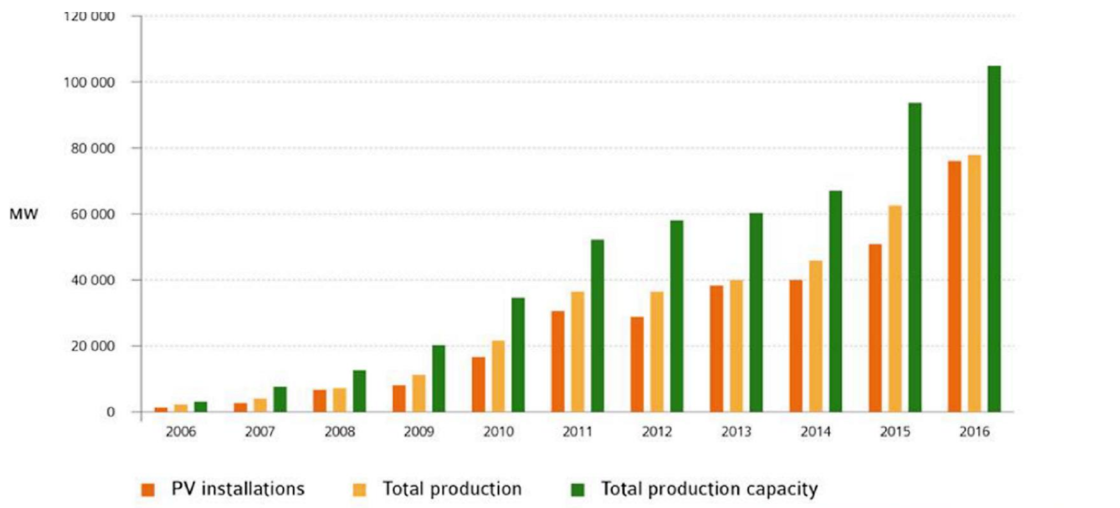

Figure 4.1: Annual PV installation, production and production capacity, 2006 ï 2016.
Source: IEA PVPS.

PV cells production is dominated by Asian countries with China, Taiwan, Malaysia and South Korea and Japan producing 94% of the total world production of solar cells in 2016. China, Taiwan, Malaysia and South Korea produced 66%, 12%, 8% and 5% respectively.

PV module production follows a similar pattern except for the absence of Taiwan in the top 5 producers. China, South Korea, Malaysia and Japan produced 69%, 7%, 7% and 4% respectively.

The evolution of PV production by region is apparent from Figure 4.2. The gradual shift of production from Europe, America and Japan to China is very clearly observed.

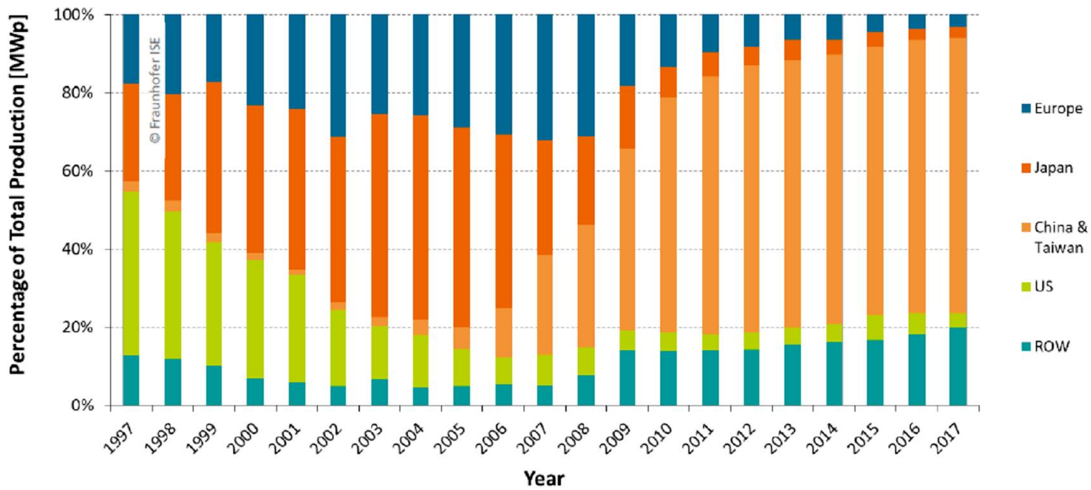

Figure 4.2: Annual PV Modules Production by Region, 1997-2017.
Fraunhofer ISE: Photovoltaics Report, 2018

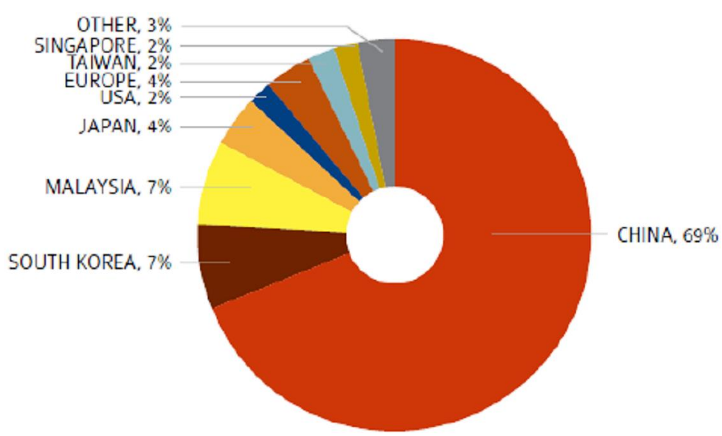

Figure 4.3: Share of PV module production, 2016.
Source: IEA PVPS

The PV market has been growing exponentially for the last 20 years. Figure 4.4 shows the growth trend over the last 27 years.

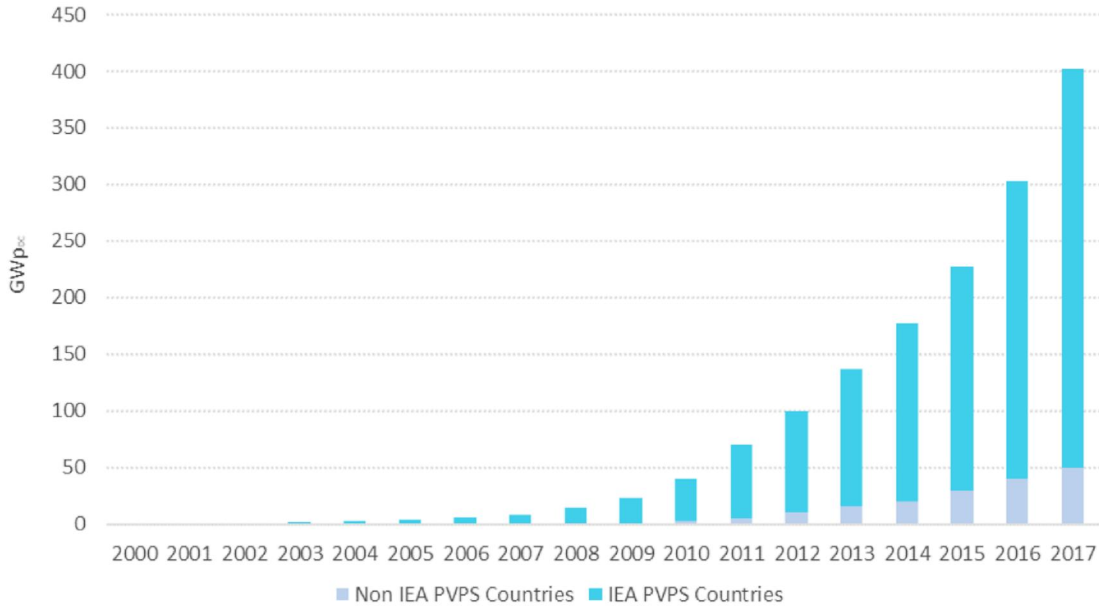

Figure 4.4: Global PV installed capacity trend, 2000-2017
Source IRENA.

The same growth trend is observed even at regional levels, save for America as can be seen from Figure 4.5.

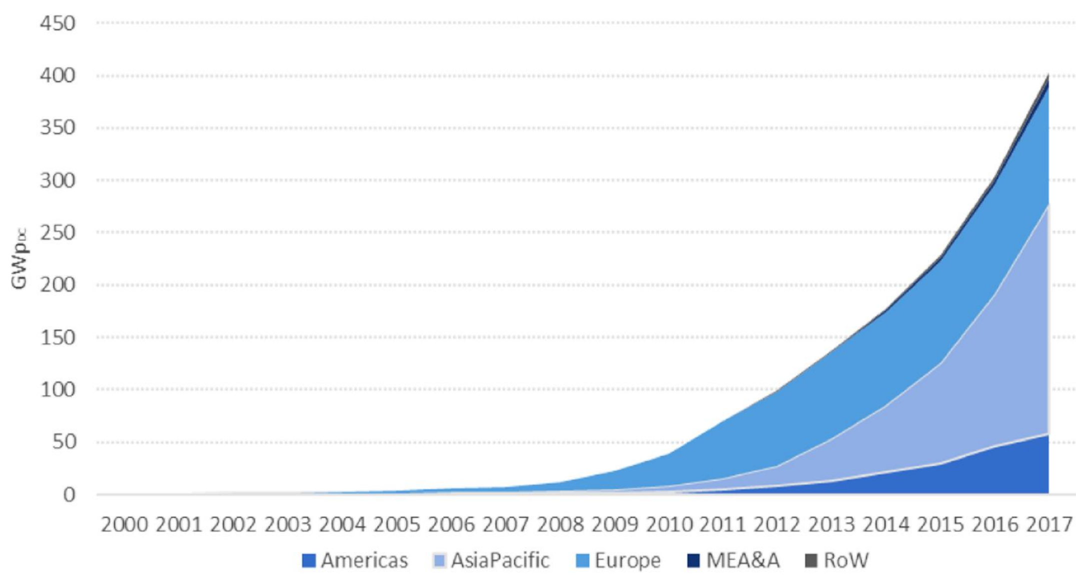

Figure 4.5: Regional PV installed capacity trend, 2000-2017.
Source IRENA

The global PV market for 2017 was 98 GW, having risen by 22GW from 76 GW in 2016 and the main markets are in Asia, Europe, Americas and the Middle East.

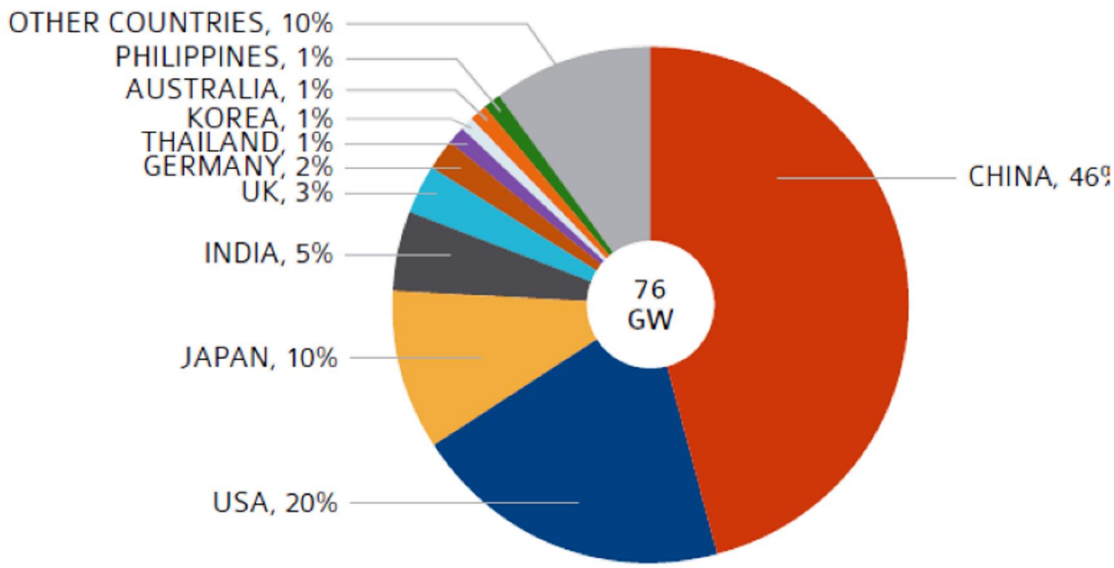

Figure 4.6: Global markets for PV, 2016.
Source: IEA PVPS

Asia is now the leader of the Global PV market in terms of production and consumption. China, India and Japan lead the pack. Other Asian markets have significant markets with Australia and Korea registering about 1GW each. Pakistan, Taiwan and Thailand have a combined market of about 1.5GW. Many other markets in Asia are developing such as Malaysia, Philippines, Vietnam and Indonesia.

In the Americas, the US market is commanding the lead followed by Brazil. Chile, Canada and Mexico are the other significant markets in the region

In Europe, Germany followed by UK, France, Netherlands and Italy in that order are the main PV markets. Almost all the European countries have some PV market share.

In the Middle East, Turkey followed by Israel, UAE and Saudi Arabia are the major markets.

In Africa, South Africa became the first African country to install close to 1 GW of PV in 2014. In 2017, its growth stopped abruptly with only 13 MW installed, after 500 MW installed in 2016. Algeria installed about 50 MW last year, but it is expected to launch a tender for 4 GW in 2018. Kenya is installing a 50MW grid-connected system to be commissioned in 2018.

Many countries have announced projects, with Egypt leading the pack (5 GW have been announced) but so far, most installations have been delayed or are still in the project evaluation phase.

4.2 Market Segments

The Global PV market can broadly be broken down into two key market segments. Grid and off-grid markets. The grid market refers to the market for residential, commercial or utility scale PV system of any capacity that are connected to the national or regional power grid in which export or import of power from the grid and vice-versa is allowed to take place. Grid PV (GPV) systems produce AC power. The off-grid market refers to the market for PV systems of any capacity that are not connected to any power grid. Off-grid PV (OGPV) systems may be plug and play products such as solar lanterns and solar lighting kits, solar home systems, stand-alone systems and mini-grid systems. OPV systems can produce AC or DC power or both. In both cases, how the generated PV power is utilized is not considered in this breakdown. It may be for self-consumption, it may be for sale to the power grid operator or a third party or both where mechanisms such as net metering and feed-in-tariffs are in operation.

In section 4.1, the PV market growth is described in general and the installed PV systems information provided includes both OGPV and GPV systems.

Figure 4.7 shows the annual share of off-grid and the Grid connected PV systems for 20 years up to 2016. In the chart, the grid connected systems are broken down into centralized systems and decentralized systems. Centralized systems are large utility scale PV systems that feed the power to the national grid. Decentralized systems are usually small-scale PV system that have capability to export or import power from the grid and vice-versa. A typical example is the residential roof-top PV grid-tie systems common in developed countries. Whereas decentralized systems are in the kilowatts range, centralized systems are in the megawatt range and use central inverters.

It is very clear from the chart that the market for off-grid PV, is comparatively small and has been declining over the years. It is about 1% currently. This is not surprising when it is observed that developed and newly industrialized countries, where grid access is almost 100% are the main markets for PV installations.

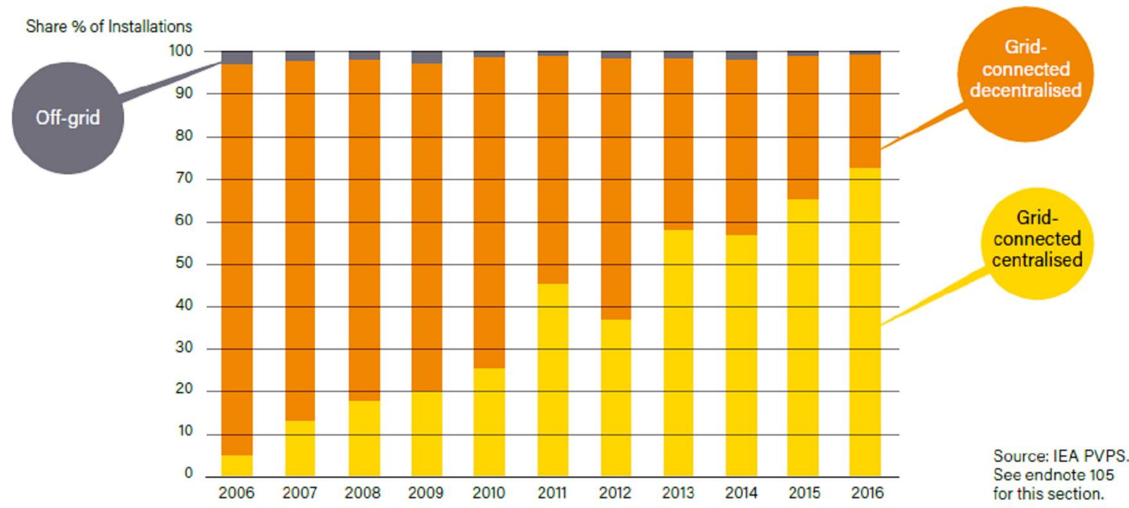

Figure 4.7: Annual share of off-grid and grid connected PV systems installations, 2006 ï 2016. *Source Ren 21.*

The off-grid market is therefore essentially suitable for developing countries mostly in Africa and Asia where grid power distribution is not widespread and electricity access and connections are low and it will take time and huge financial resources to achieve high grid connection rates.

Indeed, a REN 21 Renewables 2017 global status report [6] shows that the top five PV off-grid market countries in 2015 and 2016 are all developing countries, with most of them in Africa.

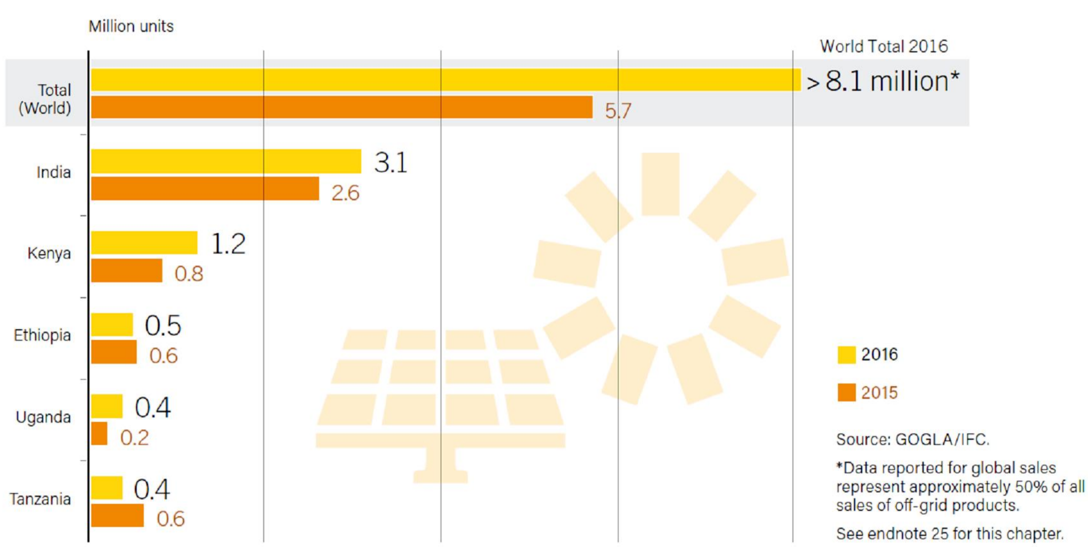

Figure 4.8: Sales of Off-Grid Solar Systems in Top 5 Countries, 2015-2016.
Source REN21.

As of 2016, more than 6 million SHS and kits were in operation worldwide, according to Lighting Global report [15], with 25 million people benefiting from them. Some 377,000 SHS (ranging from 10 W to 100-plus W) were sold worldwide in 2016; sales increased by more than 55% in the first half of 2016, to 204,000 units (compared to the 132,000 units sold from July to December 2015), and reached 172,000 units in the second half of 2016. 42 Market leaders such as M-KOPA, Off Grid Electric, d.Light, BBOXX, Nova Lumos and Mobisol served about 700,000 customers as of 2016. Bangladesh ï the largest SHS market worldwide ï now has more than 4 million units installed.

4.3 PV Market Drivers

The exponential global PV market growth has been driven by two key factors. The plummeting PV prices and market incentive schemes by Governments.

4.3.1 Declining PV prices

The rapid decline observed in the price of solar cells described in Section 4.1 was accompanied by increasing competitiveness and affordability of PV systems. This created a higher demand for PV systems.

4.3.2 Market Incentives

In the 1990ǿs, only very few and rich developed countries like the USA and Germany initiated programmes to support the PV markets in their countries. They did this not because PV was competitive but to support the growth of their local PV industries and also to assuage the international climate change concerns.

With time and particularly after 2000, the dramatic price decline made PV increasing competitiveness and encouraged more governments to initiate programmes to support investments in PV both for grid and for off-grid applications. More countries developed policies, regulations, programmes and mechanisms to encourage investments in PV for both own use and also for feeding into the grid. Developed and rich countries encouraged and supported the PV industry across the value chain ï from manufacture to end-use. At the end use level, these countries supported PV systems installations for grid connection. In developing countries in Asia and Africa however, the few countries that had support programmes initially targeted off-grid applications aimed at increasing access to basic electricity.

Over the last 10 years however, developing countries have devised initiatives to support PV markets development. China and India alone contributed over 50% of the new PV capacity installations in the world as is observed from Figure 4.6.

Historically, the main policy incentives that have been employed by governments to support investments in PV are:

- Feed-in Tariffs

- Direct subsidies or rebates
- Tax breaks
- Net-metering
- Self-consumption
- Energy auctions
- Trading of green certificates
- Regulations
- Electrification targets
- Quality Assurance frameworks

Feed in tariffs and direct subsidies and tax breaks have been most successful market support mechanisms for PV. Combined, they support 81% of the global PV markets.

4.4. Key Stakeholders

Key stakeholders in the global PV market are international organizations, national governments, Financiers, Investors and Customers.

4.3.2 International Organizations

International organizations are involved in the development and promotion of the PV market. They include UN bodies such as UNDP and UNEP; UNICEF; inter-government agencies like IEA, IRENA, IEC, Lighting Global; international NGOs like Oxfam, SNV Netherlands, GIZ; industry associations like ISES, PVUSA, EPIA, etc.

4.3.2 National Governments

National governments have played the most important role in the PV markets through policies, regulations, and incentives that have seen the PV market develop rapidly. Indeed, 99% of the global PV market has been government driven.

4.3.4 Financiers

Word Bank group, UN Agencies, Development banks, Investment banks, Venture capitalists, International NGOs, etc.

4.3.3 Investors

This category includes project developers, manufacturers and other corporates along the PV value chain, utilities, etc.

4.3.5 Customers

Major customers for PV are electric power utilities, corporates and individuals.

4.5 Major global manufacturers of PV modules and the key BOS components

PV module production is dominated by China, South Korea, Malaysia and Japan who produced 69%, 7%, 7% and 4% respectively in 2017. The consumption pattern is similar as is observed from Figure 4.6 that illustrates the global markets share for 2017.

Naturally then, the major manufacturers would be expected to reside in the major PV producing and consuming countries. The major manufacturers of PV and main BOS equipment are listed here.

4.5.1 PV modules

China dominated global shipments in 2016, for the eighth year running. Asia accounted for 90% (and China 65%) of global module production; Europeûs share continued to fall, to about 5% in 2016; and the US share remained at 2%.

Solar PV module manufacturers are many and are scattered in many countries of the world. The top 10 module manufacturers, according to PV magazine [7], who account for about 50% of PV modules production are listed in Table 4.1.

Table 4.1: Top 10 PV module manufacturers in the world, 2017.
Source: PV-Magazine

Ranking	Manufacturer name	Country	Production, 2017 (MW)
1	JinkoSolar	China	6555
2	Trina Solar	China	6405
3	Canadian Solar	Canada	6031
4	Hanwha Q Cells	South Korea	5603
5	JA solar	China	5407
6	LONGi Green Solar	China	4801
7	GCLSI	Hong Kong	4605
8	Risen Energy	China	3429
9	Yingli Green	China	3428
10	Telesun	China	3048

The other major manufacturers include Shunfeng (China), First Solar (USA). Sunpower (USA), Suntech (China), Sunpower (USA) Schott (Germany), Sharp (Japan), Zytech (Spain), Kyocera (Japan), Vikram (India), Solarworld (Germany), NeoSolar (Taiwan), Motech (Taiwan), and Sunergy (China).

There are small manufacturers in many countries of the world including South Africa and Kenya but their capacities are insignificant on a global scale.

Major PV module manufacturer whose products are available in the local market are:

- Jinko - China
- Omni Voltaic - China
- Trina - China
- Morning Star ï China
- Hanwha - China
- D.Light ï China
- Power master - China
- Daima - China
- DynaVolts - China
- Yingli - China
- Sunlight - China
- True solar - China
- Solar world - Germany
- Premier Solar - India
- Kyocera - Japan
- Ameri Solar - USA

Silicon based PV technology accounted for about 95% of the total production in 2017. The share of multi-crystalline technology is now about 62% of total production. The market share of all thin film technologies amounted to about 5% of the total annual production.

4.5.2 Inverter Manufacturers

The top ten inverter manufacturers in the world are Huawei (China), Sungrow Power (China), SMA (Germany), ABB (Finland), Sineng (China), TBEA SunOasis (China), Power Electronics (China) TMEIC, Schneider Electric and SolarEdge Technologies. These 10 commands over 70% of the market. Indeed, the top 20 manufacturers account for over 90% of the market share.

There are over 800 inverter manufacturers in the world, according to ENF solar, a PV industry database publisherôs website.

Inverter manufacturers whose products are available in Kenya are:

- Dynavolt
- East

- Magnum
- Mobisol
- MUST
- Pocasa
- Powermaster
- Schneider
- SMA
- TBB
- UNIPVO
- Victron

The market share of string inverters is estimated to be 52%. These inverters are mostly used in residential, small and medium commercial applications in PV systems up to 80 kWp. The market share of central inverters, with applications mostly in large commercial and utility-scale systems, is about 44%. A small proportion of the market (about 1%) belongs to micro-inverters - used on the module level.

4.5.3 Charge Controllers Manufacturers

There are over 500 charge controller manufacturers in the world, according to ENF solar, a PV industry database publisherôs website.

Charge Controller manufacturers whose products are available in Kenya include:

- Victron
- MUST
- Outback
- Beijing EP Solar
- D.light
- Powermaster
- Mobisol
- Viewstar
- Steca
- Dynavolt
- Morning star
- Apollo solar
- Solar max
- SMA
- Xlicton
- Deit
- Omni votaic

4.5.4 Solar Batteries

There are over 600 solar battery manufacturers in the world, according to ENF solar, a PV industry database publisherôs website. These are scattered around the world and almost every country including Kenya has a storage battery manufacturer.

The only local manufacturer of solar batteries is Associated battery Manufacturers (ABM) All the other batteries are imported from around the world.

International manufacturers whose solar batteries are available in the local market are:

- Gaston battery - China
- Rolls Battery - Canada
- Sunlight - Greece
- Hoppeckke Batterien - Germany
- BAE Batterian - Germany
- D.Lights - China
- Ritar Power - China
- Mobisol - Germany
- Dayliff - China
- Dynaolts Power -China
- Pioneer - Korea
- Victrons Energy - Netherlands
- Trojan Batteries - USA
- Loech international technologies ï China
- Power Plus ï China
- Saku ï China
- Su-kan ï India
- Champion ï China
- Incoe ï Indonesia
- Pioneer - Korea

5 KENYA PV MARKET CHARACTERISTICS

5.1 Key stakeholders

Key stakeholders in the local PV market are the national Government, Non-Government Organizations, Financiers, Investors and Customers.

i) International Organizations

International organizations have for a long time played a key role in the development of the local market. They are involved in financing PV projects, capacity building, promotion and awareness creation. They include the World Bank group, both IDA and IFC and UN agencies such as UNICEF and UNDP, GEF, bilateral development partners such as UKAID, USAID JICA, GIZ, etc., international NGOs like Oxfam, SNV Netherlands, GVEP, etc.

ii) National and County Governments

Kenyan government has played a key role in the development of the local PV markets through policies, regulations, and tax incentives that have seen the PV market develop more rapidly. Over the last 10 years, the Government has been a major financier of PV projects targeted at public institutions. The county governments have also been the main market for solar street lights.

iii) Financiers

The main financiers of PV investments have been the Word Bank group including IDA and IFC, Development banks, commercial banks, International NGOs, local NGOs, Micro-finance institutions and SACCOs.

iv) Investors

This category includes project developers, manufacturers and other corporates along the PV value chain, utilities, etc.

v) Customers

Major customers for PV in Kenya are private individuals, development partners and NGOs, governments agencies and institutions, private institutions and corporations. Private individuals command the largest share of the market.

More details about customers by market segments are provided in Chapter 7.

5.2 Legal, Regulatory and Institutional Framework

5.2.1 Legal and Regulatory

The energy sector is governed under the Energy Act No. 12, 2006 which was enacted to facilitate implementation of the energy policy prescribed in Sessional paper No. 4 of 2004 on Energy.

The Energy Act created several institutions and gave them legal mandates to undertake activities aimed at creating an orderly and friendly business environment in the energy sector. This law created and mandated ERC to regulate the renewable energy (RE) sector, which was not under any regulation before then. The law also mandated the Minister of Energy to undertake promotion of renewable energy.

Four main developments touching on solar PV industry have taken place: -

i) Introduction of the feed-in-Tariffs (FiTs) policy and regulations in 2008.
iii) Formulation of the ōThe Energy (Solar Photovoltaic Regulations)ô in 2012.
iv) Continued formulation of more PV standards and codes of practice
v) Enforcement of the Regulations

i) and ii) have had profound impact on PV. FiTs created a mechanism to encourage private sector investments in RE. The 2012 regulations put in place systems, processes and procedures for proper conduct of PV business including licensing, training and certification of technicians, systems design and installation, quality control etc., requirements of all practitioners and stakeholders in the PV industry in Kenya to ensure quality products and services are offered to the customers and also encourage accountability.

The impact of the above was assessed during the survey. Business enterprises and other key stakeholders were asked to indicate whether the enactment and enforcement of the above regulations had achieved the intended impacts comparing the period before and after 2012, when they came into force. They were asked to indicate their level of agreement with statements of five intended impacts achievement. The results are shown in table 5.1

Table 5.1: Results of the stakeholdersô assessment of the impacts of the introduction of PV regulations

Statements of Impact of the Regulations	**No. of respondents who 'Agree Strongly' (%)**	**No. of respondents who 'Agree' (%)**	**No. of Respondents who 'Disagree'**	**No. of Respondents who 'Disagree Strongly'**
Brought order in the PV market	27	60	7	7
The quality of PV products and components available in the market has improved	13	69	19	0
The installation quality of the systems has improved	14	50	36	0
Systems performance has improved	6	50	44	0
Reported systems failures and malfunctions have gone down	6	47	35	6
Overall impact	**13.2**	**55.2**	**28.2**	**2.6**

It is observed that 68.4% of the respondentsô state that the regulations had a positive impact on the industry and that they achieved the intended purpose. However, the 32.6% who state otherwise is very significant number and shows there are still issues that need to be addressed.

More specifically, the installation quality of the systems and PV performance which reflects on system failures have been ranked low and therefore need more attention.

Both the existing Energy Policy and the Energy Act are currently under review.

5.2.2 Institutional setup

The energy sector players comprise of the oversight agencies which are government institutions, the producers, transmitters, distributors, retailers and consumers. Only institutions that have relevance to this report are included here.

i) Ministry of Energy

The Ministry of Energy is responsible for policy formulation and overall energy sector planning and regulation. Resource mobilisation is one of the key functions.

ii) Energy Regulatory Commission

The Energy Regulatory Commission takes care of sector regulation both technical and economic covering all sub-sectors including electricity, renewable and down-stream petroleum. Its core mandate is licensing for all undertakings in the energy sector and enforcement and review of regulations, codes and standards for the sector.

iii) Kenya Bureau of Standards

Kenya Bureau of Standards is the legally mandated national institution that sets and enforces products standards and codes of practice. KEBS has over 20 standards and codes of practice governing PV systems and components.

iv) The Energy Tribunal

The Energy Tribunal was established in 2007 and is charged with dispute resolution between sector players. It is fully funded by the Government of Kenya.

v) Kenya Electricity Generating Company

Kenya Electricity Generating Company Limited (KenGen) generates electricity and sells it in bulk to the power distributors in the country. KenGen is a state corporation and it is listed in the Nairobi Stock Exchange.

vi) Kenya Power and Lighting Company

Kenya Power and Lighting Company (KPLC), has been, until recently the sole transmitter and distributor of electricity in the country. It is partly owned by the state and it is listed on the Nairobi Stock Exchange.

vii) Kenya Electricity Transmission Company of Kenya (KETRACO)

The Kenya Electricity Transmission Company of Kenya (KETRACO) was incorporated in 2008 and is charged with accelerating transmission infrastructure development. It is a state corporation and is fully funded by the Government of Kenya (GoK) for the construction of new transmission lines. It is expected to charge a nominal wheeling tariff to cover operation and maintenance (O&M) costs.

viii) Rural Electrification Authority

The Rural Electrification Authority (REA) was established in 2007 to enhance the implementation of the Rural Electrification Programme. It is the Government's implementing agent for rural electrification projects, both on and off-grid and is mandated to utilize renewable energy technologies where appropriate.

ix) Independent Power Producers

Independent Power Producers (IPPs) are private sector investors who generate electricity and sell it in bulk to the power distributors under a long-term power purchase agreements (PPAs). They generate power from various sources of energy including solar energy.

5.3 Historical perspective and growth trends of the Kenya PV market

The Kenya PV market started off in the seventies as a specialist PV systems service to provide power to telecoms OEMs and utilities for use at radio repeater and TV booster sites located in remote areas without grid connection and on hills where delivery of diesel fuel for generators was very difficult, particularly during rainy seasons due to lack of all-weather roads. The benefits of PV for remote power use was then captured by United Nations bodies such as UNICEF and NGOs working in remote areas such as Oxfam. UNICEF and the Ministry of Health started replacing Kerosine Vaccine Refrigerators in remote area health centres and providing basic lighting and NGOs started using PV power in their remote offices. As PV awareness rose some other institutions such as schools that could afford or got financiers (mainly NGOs) started to install solar systems. Individuals who could afford the systems started acquiring them for their households as grid connectivity was extremely low and fairly expensive. During this period, there were a couple or so PV companies who were sole agents of foreign manufacturers such as ARCO and BP Solar.

The rising interest in PV and its observed benefits created business opportunities and entrepreneurs were quick to exploit them. In the eighties, more entrepreneurs ventured into the business and some others diversified their products portfolio to include solar. By 1990, over 10 companies had ventured into local solar PV business and one multi-national, BP solar had opened a regional office in Nairobi to promote its business. By the year 2000, many companies had ventured into the business and solar products had even become commoditized and were being sold at higher purchase retail shops.

The declining PV prices, introduction of quality standards by the Government, training of technicians and marketing and promotion initiatives by companies, NGOs, and international programmes such as photovoltaic market transformation initiative fuelled the market growth. The inclusion, in 2006, of PV as a rural electrification alternative by Ministry of Energy in order to accelerate the electrification of public institutions raised the demand dramatically in the following years.

Since Kenya was not a PV modules producer until recently and most companies continue to import, then historical evaluation of importation statistics from KRA are a good representation of the local PV market trend.

Figure 5.1 represents annual PV devices importation into Kenya. The data has been extracted from KRA importation statistics. It is observed that there has been a rapid growth in demand for PV in the Kenya market. The demand has risen from 360,370 units in 2010 to 2,561,681 units by 2017. This represents an average annual demand growth of 87%.

It should be noted that the Harmonised Coding system that classifies products includes transistors, solar cells and other photo-sensitive devices in the same code number as PV modules. The assumption in this assessment is that the greater number of these devises are PV modules.

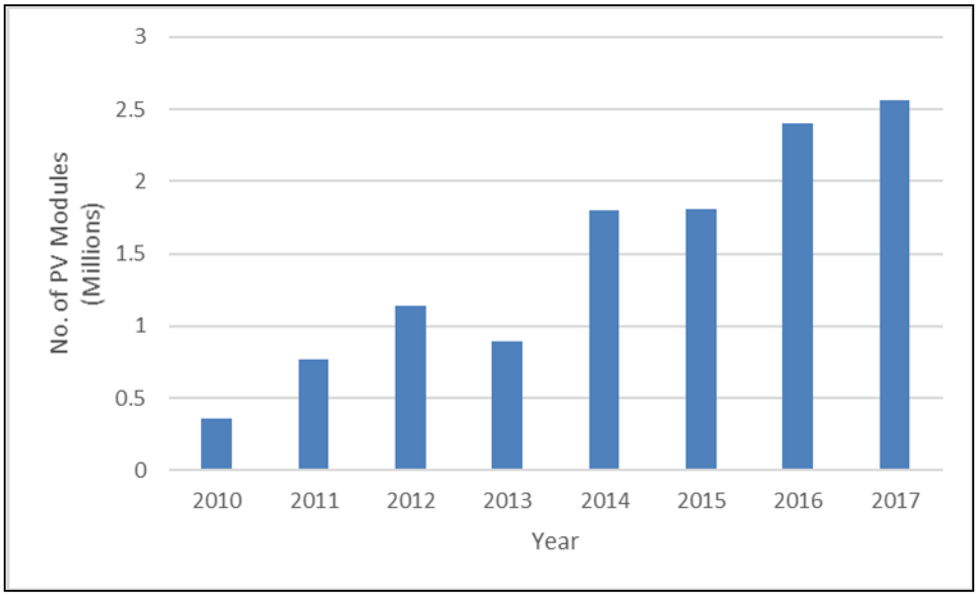

Figure 5.1: Annual PV module imports into the country, 2010-2017.

Enabling policies, laws and regulations and structured training courses have been introduced over the last 10 years to create order, and enhance service delivery. This combined with continued global price decline of PV have continued to boost the market growth.

The main drivers of the rapid growth of the PV market in Kenya over the years can thus be summarized as:

i) Lack of grid power connections in rural and remote areas
ii) High solar insolation in Kenya
iii) Donor influence in adoption of the technology for provision of power in remote locations (school Lighting, vaccine refrigeration and lighting in rural clinics water pumping for village's etc.). This helped in the dissemination of the technology locally and particularly in the rural areas in the early and mid-90ôs
iv) Falling module prices (internationally and removal of import duties combined with rising and stiff competition)
v) Ready availability of modules and Balance of System (BOS) components from local dealers.
vi) Entrepreneurship by local businessmen (they were able to see the market potential and duly went ahead to develop and exploit it)
vii) Growing incomes and high demand for modern lifestyles (electric lighting, TV, Radios etc.) among the rural based educated middle class (teachers, businessmen, farmers etc.)
viii) Promotion through mass media advertising by companies
ix) In the recent past, projects such as the Governmentôs PV electrification of schools and health centres and IFCôs Lighting Africa project.
x) Enabling policy, legal, regulatory and business environments
xi) Poor grid power reliability

5.4 Market Size

The market size was estimated from importation statistics and limited data provide by a few companies. The declared total annual shillings values was divided by the estimated average landed cost per watt for the year to arrive at the annual capacity demand. The results are presented in Figure 5.2. It has been assumed that all items brought into the country under the solar cells and modules were PV modules. This should be the case but solar industry sources indicated to the study that other items such as solar batteries, controllers, solar lanterns are at times brought in using the HS code for PV modules to avoid paying taxes on them.

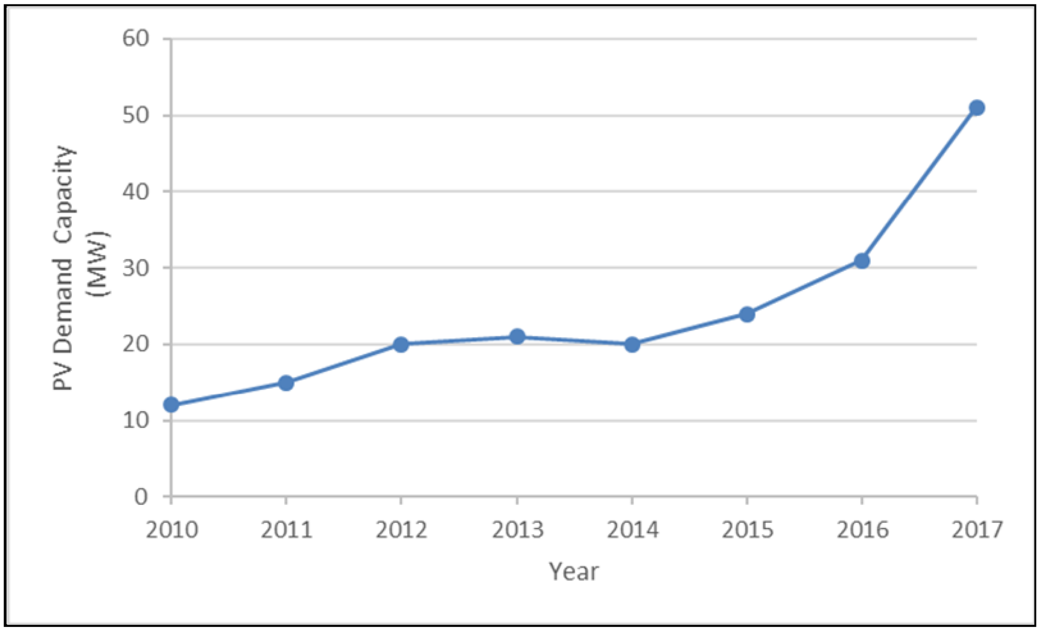

Figure 5.2: Annual estimated local PV demand capacity, 2010-2017.

Figure 5.2 shows that the market has had an almost linear growth of about 30% per annum up to 2016.

5.5 Market Segments

The PV market started off in the seventies as a mainly stand-alone power systems for professional applications serving mainly telecoms market and other specialized applications such as cathodic protection and medical refrigeration. The systems were mostly high power systems. With declining prices, individuals could afford small PV systems that are generally described as solar home systems (SHS). In the eighties and nineties, most common and affordable SHS capacities ranged between 10 and 50Watts peak (Wp). These systems were mostly DC and were basically used for lighting and operating electronic appliances mainly TVs. With plummeting prices, institutions and governments created a demand for higher capacity systems for off-grid use. These systems are over 100W and can get all the way to 2000W and almost always AC. These can be described as stand-alone power systems.

The above have been the traditional PV systems being marketed in the country until recently when new market segments emerged.

Even though there have been solar lamps and packaged lighting kits for a long time in the market, a recent initiative driven by the world bank group, lighting global, have seen the proliferation of high-quality lanterns and low power packaged, plug-n-play (PnP) PV systems. They are mainly meant to provide lighting and limited charging of mobile phones. These have been described in the said initiatives as pico-solar and plug and play (PnP) solar home systems. For the purposes of this report, we shall treat solar lanterns as separate from these PnP kits and because they are principally meant for lighting and to differentiate them from the higher capacity solar home systems.

Some investors, community groups and the government agencies such as REA and KPLC have created a mini-grids market for PV and PV-Diesel hybrid systems. With mini-grids, a centrally generated PV power, complemented diesel generators or battery storage or both is connected, through a local distribution system, to several consumers. These mini-grids are meant to cost effectively accelerate rural electrification. Many county governments, institution and even corporates have adopted solar PV for area security or streets lighting creating another market segment. In most parts of the arid and semi-arid areas of Kenya, mostly parts of Eastern Kenya, North-Eastern, Coast and parts of Rift Valley, NGOs, County Governments use solar powered pumps, mostly borehole solar pumps for provision of water to communities and institutions. This has largely been the driver for increasing demand for solar water pumps. Hence there is another market segment for solar water pumps.

The above description of the existing PV products meant to address a specific need for different consumer groups results in seven PV market segments.

Table 5.1. PV market segments

Item No.	Market Segment	Target Customer	Typical capacity Range
1	Solar Lanterns	Individuals- low income	0.5W-10W
2	Solar Home System	Individuals - middle income	10-200W
3	Stand-alone Power Systems	Institutions	200W-2000W
4	Street /area Lighting	Institutions, corporates and county governments	50 ï 200W
5	Solar pumping systems	Institutions, county governments.	Above 200W
6	Mini-grid	Off-grid settlements/communities	1kW ï 1000kW
7	Utility-scale solar	Institutions and Corporates for captive power and grid operator for feeding into the grid	Above 500kW ï

5.6 Supply Chain

Kenya has one PV module manufacturer. The country has one solar battery manufacturer. The other key PV components are imported into the country.

The local PV manufacturer markets its PV modules through distributors who also happen to be importer of one or more PV components that are not manufactured in the country or they could be cheaper sourced from other countries. These could be modules, batteries, inverters, charge controllers and also integrated packages such as lanterns and SHS and some load appliances such as lamps and pumps.

The supply chain therefore involves manufacturers, local and foreign, importers/distributors, dealers, retailers, installers and the customer. Solar PV systems require technical expertise for integration and installation. This is very necessary for all market segments except for the packaged systems such as solar lanterns and lighting kits where rudimentary knowledge, guided by a user guide is adequate for operating the kits. In all other cases, properly trained technicians and engineers have to get involved in the design and installation work. Hence the need for installers who may be operating as freelance technician or a company such as the distributor/importer, dealer who has in-house engineering capacity. Most dealers and distributors have internal engineering departments that undertake the engineering of the PV systems from design to installation and maintenance.

Figure 5.3 summarizes the PV products supply chain. The supply chain caters for almost all possible scenarios for delivery of product from manufacturer to end-user. Kenya not being a manufacturing country for most PV products, importation and accompanying costs of marine shipping canœt be avoided. Clearing and forwarding to the Distributorœs warehouse canœt be avoided either because distributors have to procure in bulk. Distributors and dealers usually undertake the selling and installation work themselves. So, in most cases the installer is also the distributor or dealer. Some major distributors have branches in major towns, where they directly sell to customers and also undertake the installation. In some cases, especially where small simple systems are involved, dealers/distributors tend to hire freelance installers, who tend to be fairly cheap compared to the installation by the dealer themselves. Freelance installers also serve as marketing agents for dealers. So, they identify and advise customers on appropriate systems and direct them to dealers. The customer buys the components and the technician undertakes the installation.

The solar lanterns and integrated SHS do not require technical proficiency so they bypass the installer. They therefore are off-the-shelf products.

The lanterns and SHS products have become more like commodities. One will find solar lanterns, SHS and components such as panels, batteries, controllers and even inverters in supermarkets and general electrical appliances outlets in most urban centres in the country. In downtown Nairobi, around Luthuli Avenue which is famous for electronics appliances, this survey counted 23 shops that stock these solar products.

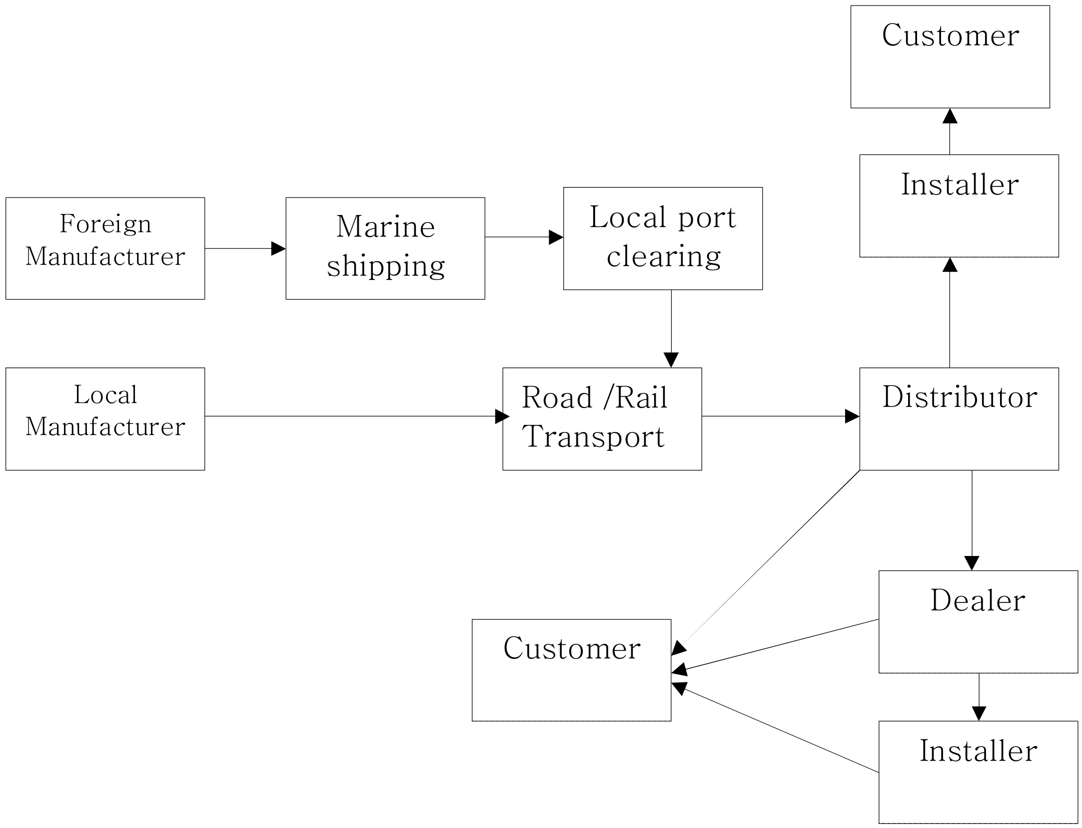

Figure 5.3: PV products supply chain

The main outlets for solar lanterns and packaged kits and SHS components ae electrical and electronic appliances shops and supermarkets and hire-purchases shops. For the stand-alone, security lights, solar pumps and off-grid and grid-connect systems the distributors and dealers provide these services directly to customers.

5.7 Source markets

5.7.1 PV modules

Kenya has only one manufacturer of PV modules, Solinc East Africa Limited This company assembles PV modules of 5, 10, 20 80, 150 and 250Wp.

All the other PV modules and BOS components are imported into the country from various companies and countries.

Analysis of PV modules importation statistics shows that China is the principal source of PV modules into the country. Importation of PV modules from china has grown from 60% in year 2010 to 98% in year 2017.

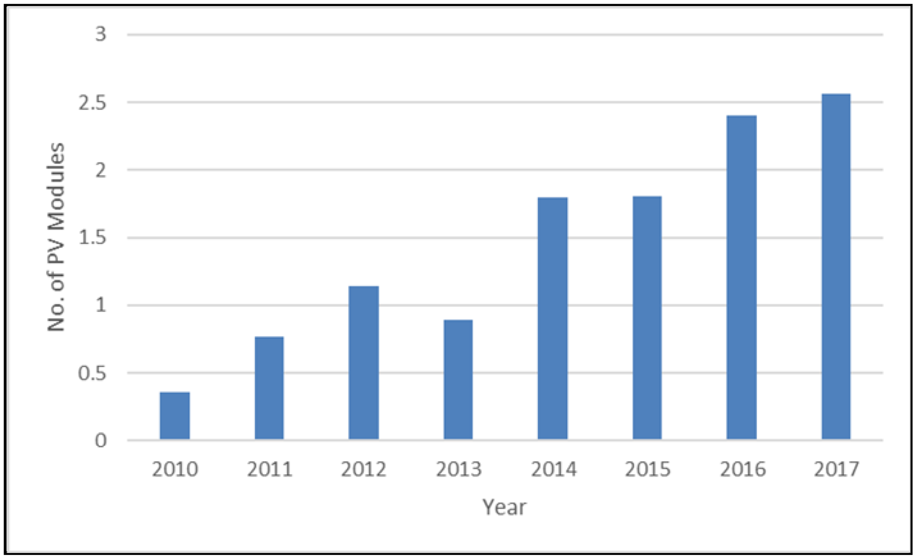

Figure 5.4: Annual PV module imports into the country

Figures 5.5 and 5.6 show the breakdown of imports by source countries, in percentages, for year 2010 and 2017 respectively.

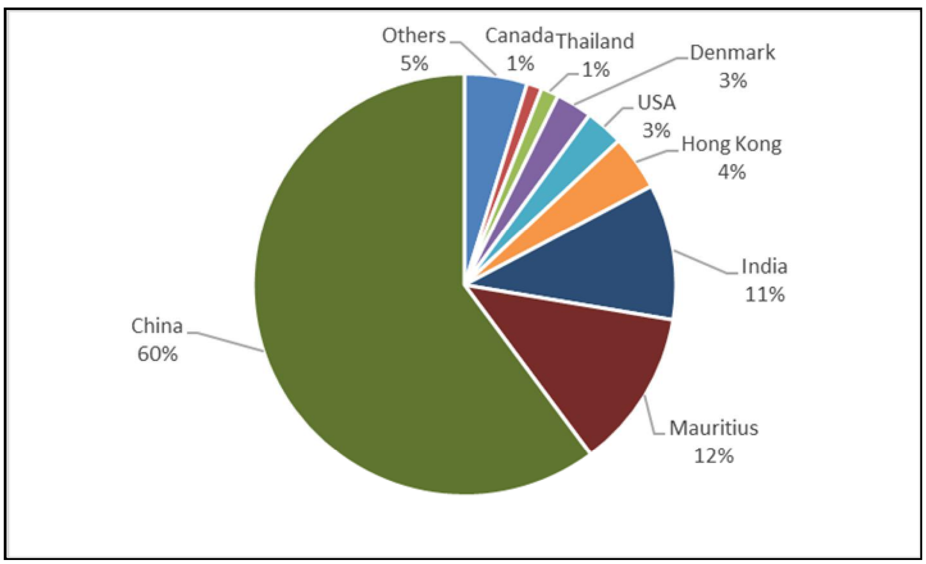

Figure 5.5: Source countries for PV modules into Kenya, 2010

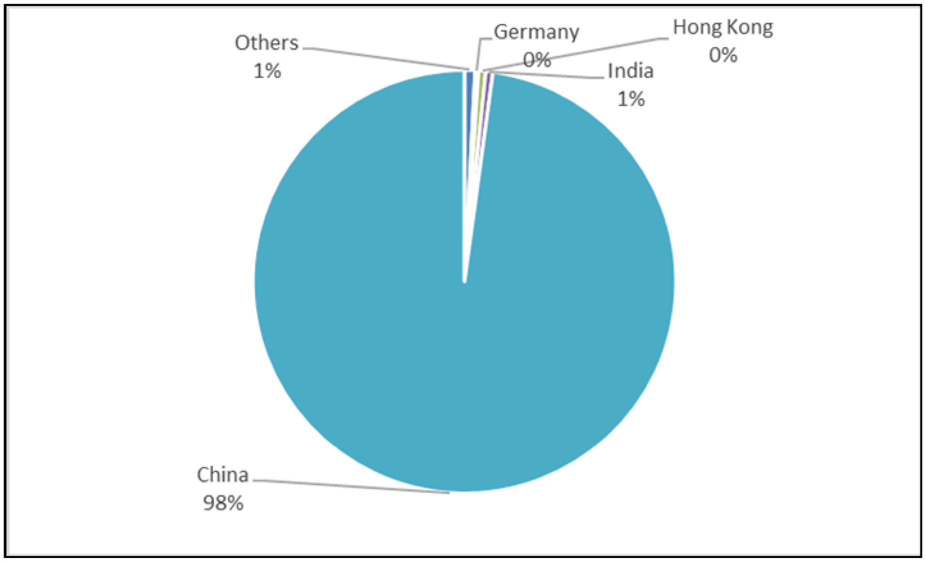

Figure 5.6: Source countries for PV modules into Kenya, 2017

It is observed that China has increased its market share for PV modules within seven years from 60% to 98%.

From the market survey, 20 local companies, that make up 63% of the respondents import PV modules from China. The remaining companies import from Germany (3), India (2). Japan (2), USA (4) and England (1).

China is almost exclusively the source of all imported PV modules for Kenya.

5.7.2 BOS Components

The key PV BOS components are Inverters, solar batteries and Charge Controller.

i) Solar batteries

Kenya has one local manufacturer of solar batteries ABM. These batteries are marketed under brand name Chloride Exide, the name of the sister marketing company.

All the other solar batteries are imported into the country and importation statistics from KRA would have been the ideal source of data on source countries of the other batteries. Importation data would have provided at least the number of units and country of origin. However, solar batteries do not have a specific classification under the international Harmonized Commodity Description and Coding System (HS). Consequently, the solar battery is lumped together under HS code 850720000 for ôElectric accumulators, including separators therefore, whether or not rectangular (including square). - Other lead-acid accumulators since most solar batteries are lead acid. This lead acid battery classification excludes only the lead acid starter batteries meant for starting vehicles. This means that other than for starter batteries, all other lead acid batteries (UPS, standby, traction, etc.) are lumped together under this categorization. This makes it difficult to determine which batteries imported were meant for solar applications.

Of all the lead acid batteries imported in the years 2015, 2016 and 2017 under this HS code, China supplied 49%, 98% and 79% respectively. This implies that China is still the source country of most solar batteries.

From the market survey, 19 local companies, that make up 56% of the respondents import solar batteries from China. The remaining companies import from Germany (5), India (3). Greece (3), Canada (2) and Indonesia and South Kore one each.

ii) Inverters

There is no manufacture of inverters being undertaken in the country. Therefore, importation statistics from KRA provide a good picture of the source countries for inverters.

However, as is the case with solar batteries, inverters do not have a specific classification under the international Harmonized Commodity Description and Coding System (HS). Consequently, the inverter is lumped together under HS code 850440000 for óElectrical transformers, static converters (for example, rectifiers) and inductors. - Static convertersö. This makes it difficult to determine which converters were actually imported for solar applications.

From the importation data for the years 2015, 2016 and 2017 under the above HS code, China supplied 90%, 67% and 91% respectively. This implies that China is the main source country for inverters.

From the market survey, 15 local companies, which make up 50% of the respondents import inverters from China. The remaining companies import from Germany (9), France (3), India (1), Taiwan (1), and Italy (1).

China and Germany are the key source countries for inverters for Kenyan market.

iii) Charge Controllers

Just like Inverters, there is no manufacture of Charge Controllers being undertaken in the country. So they are all imported.

As is the case with Inverters, Charge controllers do not have a specific classification under the international Harmonized Commodity Description and Coding System (HS). Consequently, the Charge Controller is lumped together under HS code 9032890000 for óAutomatic regulating or controlling instruments and apparatus. ï Otherö. This makes it difficult to determine which Regulators were actually Charge Controllers meant for solar applications.

Of all the automatic regulators imported over the last three years under this HS code, China supplied 71%, 61% and 61% in 2017, 2016 and 2015 respectively. This implies that China is the main source country of charge controllers.

From the market survey, 15 local companies, which make up 60% of the respondents, import Charge Controllers from China. The remaining companies import from Germany (28%). USA (8%) and Taiwan (4).

Therefore, China and Germany are the key source countries for Charge Controllers for the Kenyan market.

5.8 Major Market Players

This section focuses on the main players along the supply chain. They include manufacturers, importers and distributors, dealers and customers.

5.8.1 Local Manufacturers

There are only two local manufacturers of PV products.

Solinc East Africa is the only local manufacturer of PV modules. They make panels of between 5 and 300W. The 5 to 10W range serve the packaged systems (lanterns and lighting kits) market. The higher power modules serve the SHS, stand-alone institutional and utility scale markets.

Associated battery manufacturers (ABM) is the only local manufacturer of solar batteries, all 12V with capacities of 32 Ah,50 Ah,75 Ah, 100 Ah and 150 Ah.

5.8.2 Importers and Distributors

The Energy Regulatory Commission had, as of May 2018, licensed 183 companies in the category of manufacturers and importers, License Class V2. The total number of PV licensees is 230 therefore 78% are registered as importers. These are also the main distributors of PV products. During the survey, it was established that most of these companies buy most of their components from major local importers/distributors even though they also may import a few components for putting together PV systems.

Currently there are about 20 major importers/distributors of PV products in the country. These are listed below.

i) Sollatek Electronics Ltd
ii) Telesales Solar
iii) Chloride Exide
iv) Center for Alternative Technology
v) Davis & Shirtliff
vi) Powerpoint Systems E.A Ltd
vii) Asachi Limited
viii) Power Options Limited
ix) Go Solar
x) Solargen Power

xi) Suntrasffer
xii) Harmonic System Co Ltd
xiii) Daima Energy
xiv) Transafrica Water
xv) Aston Field
xvi) Greenlight Planet
xvii) Orb Energy
xviii) Dream Ep Global Energy
xix) D.Light
xx) Delta
xxi) Dynavolt Technology(K) Ltd
xxii) Mobisol Kenya Limited

5.8.3 Dealers and Retailers

The Energy Regulatory Commission had, as of May 2018, licensed 139 companies in the category of dealers, License Class V1. Out of these, 120 do have the other class of licenses, C1 or V2 or both. This leaves on 19 licensees who are strictly dealers according to the law.

The local market is littered with PV dealers most of them unlicensed. According to Lighting Global [15], there are over 1500 retailers of solar lanterns and lighting kits in Kenya. In a survey undertaken in year 2011 [16] 70 small businesses mainly, electronics shops, along the major highways to Kisumu, Kakamega, Mombasa, Garissa and round Mount Kenya were found to be selling solar products. Supermarket chains, higher purchase retail chains too are dealers of PV components, more so packaged products. A major oil marketer sells lanterns and kits in all its fueling stations.

During the survey, it was established that most of the dealers and retailers buy most of their components from major local importers and distributors even though they also may import a few components here and there for putting together PV systems.

The above shows that there are so many solar PV products and components dealers in the country, most of them unlicensed. The licensed ones are primary importers/distributors. The multiple licenses by these companies show that they are the primary dealers.

The market survey has identified the following companies as the primary main dealers in PV products:

i) Sollatek Electronics Ltd
ii) Telesales Solar
iii) Chloride Exide
iv) Center for Alternative Technology
v) Davis & Shirtliff
vi) Powerpoint Systems E.A Ltd
vii) Asachi Limited
viii) Power Options Limited

ix) Go Solar
x) Solargen Power
xi) Suntrasffer
xii) Harmonic System Co Ltd
xiii) Daima Energy
xiv) Transafrica Water
xv) Aston Field
xvi) Greenlight Planet
xvii) Orb Energy
xviii) Dream Ep Global Energy
xix) D.Light
xx) Delta
xxi) Dynavolt Technology(K) Ltd
xxii) Mobisol Kenya Limited
xxiii) M- Kopa
xxiv) Dreampower
xxv) Total Energy

The secondary dealers or retailers, ranging from supermarket chains to individual freelance technicians would be in thousands. Yet they are not licensed!

5.8.4 Major Installers

ERC had, as of May 2018, licensed 129 companies under license C1 which is meant for PV Contractors, who are authorized to undertake all type of PV systems design and installation. Analysis of the companies licensed under classes V2 (manufacturers and importers) also have license class V1 (which distribute, sell and install) and many of them also have C1 license allowing them to undertake installations of PV systems of all capacities and configurations.

Analysis of the licensed PV practitioners shows that 53 have all the three license classes C1, V1 and V2. Consequently, the companies listed as importers and dealers are also the major installers. They offer the full range of services along the supply chain.

230 PV Practitioners are licensed by ERC. Only 26 of these have only Class V2 license which is for importers and manufacturers. The means that 204 (88%) of all licensees are also installers.

The major installers were identified to be the main companies who also happen to be importers and distributors and also dealers. They are listed below:

i) Sollatek Electronics Ltd
ii) Chloride Exide
iii) Center for Alternative Technology
iv) Davis & Shirtliff
v) Powerpoint Systems E.A Ltd
vi) Asachi Limited

vii) Power Options Limited
viii) Go Solar
ix) Solargen Power
x) Suntrasffer
xi) Harmonic System Co Ltd
xii) Daima Energy
xiii) Transafrica Water
xiv) Aston Field
xv) Orb Energy
xvi) Dream Ep Global Energy
xvii) Delta
xviii) Dynavolt Technology(K) Ltd
xix) Mobisol Kenya Limited
xx) M-Kopa
xxi) Solar Century

There are so many freelance electricians who undertake solar installations in both rural and urban centres. Most of them are not licensed and are certainly also not properly trained to undertake professional PV design and installation.

6 PV COMPONENTS CHARACTERUISTICS

6.1 PV Modules

i) Brands in the market

Listed below are the major PV module brands found in the local market.

- Jinko
- Omni Voltaic
- Trina
- Morning Star
- Hanwha
- D.Light
- Power master
- Daima
- DynaVolts
- Prostar
- Micro solar
- Yingli
- Sunlight
- True solar
- Sollatek
- Axitech
- Mobiso
- Solar world
- Premier Solar
- Orb Energy
- Kyocera
- Solinc East Africa
- Chloride Exide
- Ameri Sola
- Comdedinn

ii) Module types

The module types found in the market are polycrystalline, monocrystalline and amorphous silicon. The polycrystalline was most common followed by monocrystalline. The amorphous silicon modules were found with only two companies. CadTe and CIGS modules that a gaining market share at the international scene have not yet entered the local market. A-Si modules have lost ground over the years in the local market, just as is happening at the global scene.

iii) Voltage, power rating and efficiencies.

The nominal voltages for PV modules found in the market are 12, 24, 36 and 48V DC. 12 V was the most prevalent at 49% followed closely by 24V at 43%. The 36V and 48V modules prevalence was 1% and 6% respectively

The power rating of the modules ranged between 10Wp and 350Wp.

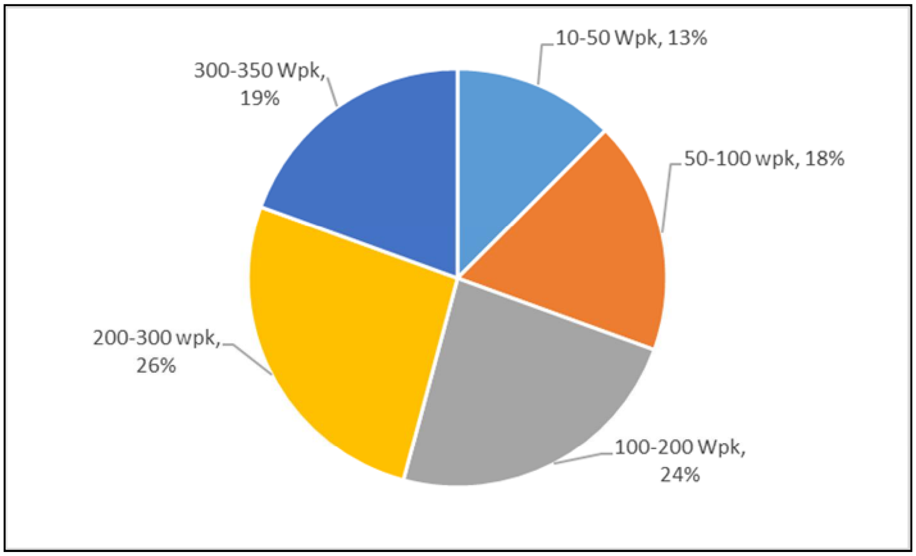

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Figure 6.1: Rated power prevalence rates of PV modules

As regards efficiencies, monocrystalline are more efficient than polycrystalline and perform better in high temperature environments.

iv) Prices

Local prices of PV modules range from KShs 1500 for a 15W module to KShs 35000 for a 330Wp module. The price per watt varies between Kshs 75 per Wp to KShs 113.30 per Wp. The average price is 98.44 Kshs/Wp.

v) Market demand and demand trends

The survey received data on sales volumes from nine businesses that have been in existence for over 5 years with most of them having been in the PV business for over 10 years. The combined annual module sales for years 2015, 2016 and 2017 were 25,000, 31000 and 35000 modules respectively. The modules were of various ratings of between 10Wpk and 350Wpk. The combined annual power capacities were 2.5MW, 2.7MW and 4.6MW for 2015, 2016 and 2017 respectively.

The global national demand estimates for PV in general was estimated using importation statistics and this is described in chapter 5.

6.2 Inverters

i) Brands in the market

Listed below are the Inverter brands found in the local market.

- Victron
- SMA
- Xantrex
- Sukam
- Delta
- Dynavolt
- East
- Eazy Inverter
- Fronius
- Hybrid
- Izzy
- Luminous
- Must
- Opti
- Orb
- Out Back
- Pocasa
- Powerhive
- Premier
- Sako
- Schneider Electric
- Silar Africa
- Sma
- Sollatek
- Steca
- Sunny Tripower
- TBB
- Tech Inverter
- True Power

ii) Inverter types

Both modified sinewave and pure sine wave types are available in the market. From the market survey, pure Sinewave Inverters have a prevalence rate of 89% while the modified sinewave has 11%.

Some SMA, Fronius, Victron and MUST inverters available in the market have grid-tie ability.

iii) Power, Voltage and Efficiency

The power rating of the Inverters in the market range between 100W and 50kW. The 100-1000W Inverters are most prevalent at 39% followed closely by the 2000-5000W range Inverters at 30%. The 1000-2000 power range prevalence rate is 15% while the prevalence rate of Inverters rated at 5000W is 15%.

The Inverters input DC voltage are 12V, 24V and 48V. There are a few high power types with input voltages of 500V and 1000V. The input voltages are very much dependent on the power rating. All Inverters of less than 1000W were 12V. At between 1000W and 3000W, most were 24V though there are a few 12V types. All Inverters rated above 3000W were 48V.

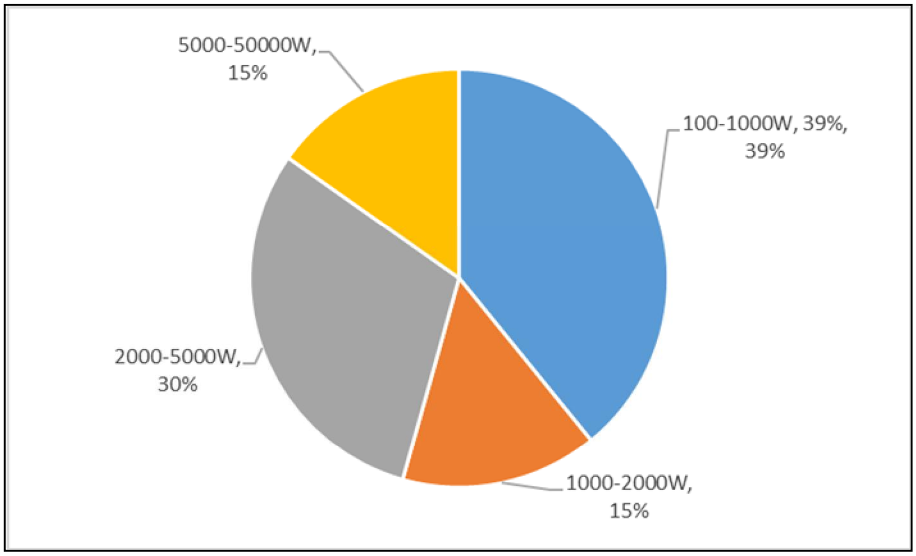

Figure 6.2: Rated power prevalence rates of the Inverters in the market

The output voltages of these Inverters are 230V AC single phase or 430V AC three-phase.

The efficiencies of the Inverters found in the market were above 90%.

iv) Prices

Inverter prices vary between KShs 7 per watt to KShs 62 per watt. The average price is 22.50 KShs/W

vi) Market demand and demand trends

Only five companies provided sales data on Inverters and for year 2017, they sold 5500 units between them. Only three of these companies can be said to have a significant market presence.

6.3 Charge Controllers

i) Brands in the markets

Listed below are the Charge Controllers brands found in the local market.

- Apollo
- Asachi
- D Light
- Delta
- Dynavolt
- EP Solar
- GP Solar
- Juta
- Morning Star
- Must
- Orb Energy
- Out Back
- Powerhive
- Scott
- SFC(PAC)
- SMA
- Sollatek
- Steca
- TPS
- Victron

ii) Charge Controller types

In terms of performance, controllers can be grouped into two types Maximum Power Point Tracking (MPPT) and Standard. The Standard may or may not incorporate pulse width modulation (PWM). The two types are available in the market and the prevalence is almost equal at 50%.

This means that local market has embraced the highly efficient MPPT types as well.

iii) Voltage, Current ratings and efficiencies

The nominal rated voltage of the charge controllers found in the market are 12V, 24V and 48V. Almost all of them are duo-voltage and can operate at both 12 and 24V. The 48V are not common.

The rating of Charge controllers is normally given in Amperes (A). The current rating of the charge controllers in the market ranges between 5A and 80A. The prevalence rates of the 5-10A controllers is 38% followed by the 20-30A range at 25%. The above 30A prevalence rate was 20%.

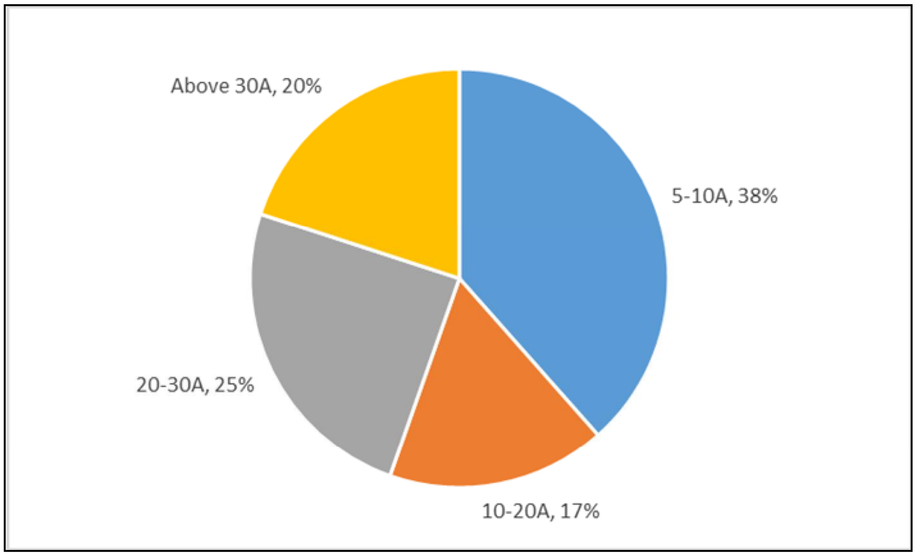

Figure 6.3: Rated current prevalence rates of the Charge Controllers in the market

These semi-conductor Charge Controller efficiencies are quite high at over 90% with MPPT types at the very top followed by PWM types.

iv) Prices

Charge Controller prices vary between KShs 200 per A to KShs 730 per Ampere. The average price is 423 KShs/A.

v) Market demand and demand trends

Only five companies provided sales data on Charge Controllers and for 2017, they sold 19000 units between them. Only three of these companies can be said to have a significant market presence.

6.4 Solar Batteries

i) Brands available in the local market

Listed below are the solar battery brands found in the local market.

- Aero Force
- Bae
- Champion
- Chloride Exide
- D Light
- Day Liff
- Dynavolt

- Flex
- Gaston
- Hoppecke
- Incoe
- Indigo
- Leoch
- Notholer
- Pioneer
- Power Plus
- Ritar
- Rolls
- Saku
- Solite
- Sollatek
- Sukam
- Sunlight
- Super Charge
- Trojan
- Victron

ii) Solar battery types

Both lead acid and alkaline batteries are available in the market but lead acid dominates with a prevalence rate of 95%. The packaging of the batteries is either vented or sealed and sealed type may be gel or flooded. The sealed battery dominates the market at 89% prevalence rate.

iii) Voltage, Capacity ratings and cycle life

The batteries are available in 2V, 6V, 12V and 24V modules. The 12V version dominates the market with a prevalence rate of 81% followed by the 2V packages at 11%. The 24V modules prevalence rate is 6%.

The battery capacities range between 7AH and 4700AH. In between there are batteries of 7 30, 40, 50, 75, 100, 150, 200, 600, 2000, 3000 AH.

The prevalence rates of the 100-200AH batteries is 43% followed by the 7-50AH range at 29%. The 50-100AH batteries prevalence rate was 18%. The 200AH battery was most prevalent at 41% followed by the 40AH battery at 16% with the 100AH battery coming third at 14%. These are all 12V batteries. This means that the three battery sizes dominate the PV battery market with a combined prevalence rate of 71%.

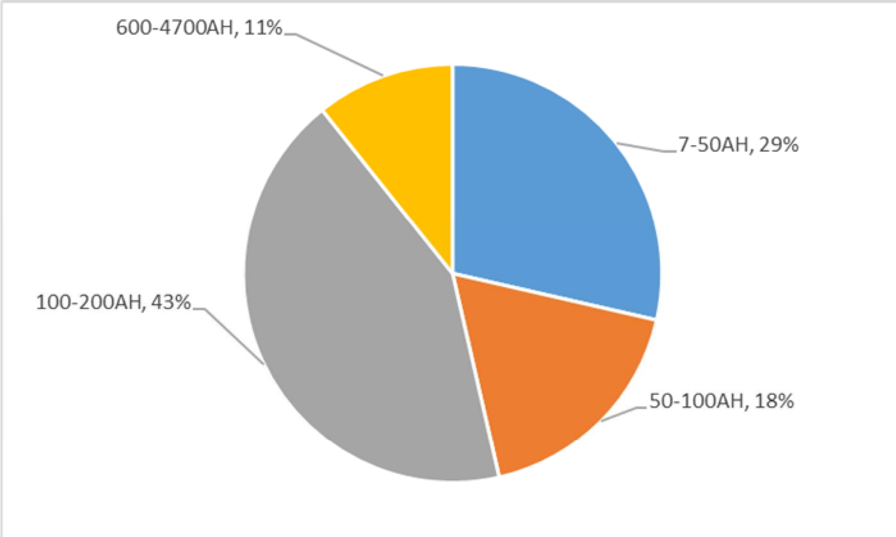

Figure 6.4: Battery capacity rating prevalence rates

All makes were reported to have good cycle life which means they can serve for about 5 years on average before they require replacement.

iv) Prices

Solar battery prices range between KShs 75 per AH to KShs 420 per Ampere. The average price is 150 KShs/AH.

v) Demand and demand trends

Only five companies provided sales data on PV batteries and for 2017, they sold 15880 pieces between them. Only three of these companies can be said to have a significant market presence.

The global national demand estimate for PV in general was estimated using importation statistics and this is described in chapter 5. This only shows that there is an increasing demand for PV which implies that battery demand would also be increasing.

6.5 Load Appliances

In Kenya, solar PV has traditionally been used for lighting and operating low power consuming devices such as lights, TVs and Radios, in homes and institutions. In the recent past, PV has become competitive and its now operating higher power loads such as pumps and has even become an energy source for feeding into the mini-grids and even national grid.

Lighting and water pumping are key applications of PV in Kenya and the survey sought to find out what lamps and pumps exist in the local market.

i) DC Lamps

Availability of DC lamps eliminates the need for Inverters that add to the cost and complexity of PV systems. There are several brands and types of DC lamps in the market. They include Lumia, Sollatek, Topolo, Sunking, Sundaya. They are available in LED, Fluorescent and Compact Fluorescent versions. The wattage varies between 6W and 18W. Most operate on 12V DC. Prices range between KShs 600 and KShs 800 per lamp.

These lamps are principally used in solar home systems.

ii) Solar Pumps

Energy efficient solar pumps reduce the size and cost of PV pumping systems. There are several brands found in the local market. They include Grundfos (Denmark), Lorentz (Germany), Shurflo (USA), Sollatek (UK), Powermik (China) and PE (Spain).

Grundfos and Lorentz were the most common in the market. The rated power varies between 300W and 15000W. The most common were in the 1000W to 5000W power range.

There are a few surface pumps but most of the pumps available in the market are borehole types.

iii) Other common PV loads

Other common load appliances include televisions, computers and refrigerators. Even though the DC versions are available, they are not common. Most of them are the standard AC powered devises that require power inverters to operate off PV systems.

7. PV SYSTEMS CHARACTERISTICS AND PERFORMANCE

The PV components described in Chapter 6 are used to put together PV systems that are used for various applications. These applications were used to differentiate market segments in Chapter 3. This chapter looks at the characteristics of each of the PV systems serving each of the market segments.

7.1 PV systems characteristics

7.1.1 Solar Lanterns

Solar lanterns are self-contained PV systems with built-in or plug-in detachable module.

i) Brands available in the market

The brands available in the market include: -

- Premier
- D.Light
- Dynavolt
- Barefoot
- Sunking from Greenlight planet
- Nikkon
- Better LED
- ORB Solectric
- Suntranssfer
- Solux
- Niwa
- Tough stuff
- Iglow
- Uno

ii) Design parameters

Most of the solar lanterns come with one solar panel of between 0.5 and 5W. These are designed to provide lighting for between 4 and 8 hours per full day charge. Most of them use LED lamps.

iii) Prices

Prices lie between KShs 500 and KShs 8000 per lamp. The average price is Kshs 3,300 per unit.

iv) Solar Lanterns penetration

Dealers did not provide sales volumes of lanterns sold in the country. According to Lighting Africa, 4.4 million certified solar lanterns and pnp units had been sold in Kenya by end of year 2017. These are the quality certified lanterns and kits. Since these are not the only ones in the market but they command a huge market presence and share, one can estimate that the number of solar lamps and kits in use in Kenya is about 5 million.

Based on the survey, average module power capacity of lanterns in the market is 3 Wp. Assuming that 80% of the units are lanterns and the rest are SHS, then the solar lanterns would be 3 million resulting in an installed estimated capacity of 9 MWp.

v) Solar Lantern Customers

The major solar lantern customers are private individuals followed by non-governmental organizations and development partners. During the survey, 70% of the companies that provided data indicated that private individuals are the major buyers of solar lanterns followed by NGOs and development partners at 18%.

7.1.2 Solar Home Systems

Solar home systems (SHS) can be split into two broad categories. The plug and play integrated packages (ISHS) and the component based solar home systems (CSHS).

7.1.2.1 Integrated SHS

The common characteristics of ISHS is that they provide purely DC power, have multiple lamps and they normally incorporate a provision for mobile phone charging and at the higher power range might have a power socket for radio or low power DC TV. They do not require specialist skills to install and operate. The Lighting Global programme refers to them as plug and play solar home systems.

i) Brands available in the market

- OmniVoltaic
- Little Dream box
- Solar Home
- Niwa Home
- Sunking Home
- Orb Solectric
- D.light
- Barefoot
- Dynavolt
- Nikkon

ii) Design Parameters

Typical SHS comes with one solar panel of between 5 and 40W. The power between 2 and 8 lights with most of them having 3 to 4 lights. They also incorporate DC charging for mobile phones. At the higher power end, they incorporate socket for powering radios, TVs and media players (DVDs and MP3). They provide lighting for between 4 and 8 hours per full day charge. Most of them use LED lamps. They provide 12V DC power.

iii) Prices

Prices lie between KShs 1800 and KShs 30000 per system. The average system price is KShs 1130 per Wp. The average system capacity is 13 Wp.

vi) ISHS Customers

The major ISHS customers are private individuals followed by non-governmental organizations and development partners. During the survey, 80% of the companies indicated that private individuals are the major buyers of ISHS followed by NGOs and development partners.

7.1.2.2 Component based SHS

i) Brands in the market

These are customized systems and are put together by distributors, dealers and installers. They therefore do not carry specific brand names.

ii) Design Characteristics

Component Solar home systems (CSHS) are the higher power mostly custom designed PV systems that solar companies put together to provide a pre-determined lighting and power solution or to suit individual customer needs. Rural technicians also integrate PV systems by putting together the various system components.

CSHS systems require skilled technician to undertake design and installation work. The PV modules are permanently fixed on house roofs. The installation of charge controllers, panel mounting structures, cables and other switchgear is also involved.

CSHS are mostly designed to provide power for other applications in addition to lighting. In most cases SHS provide power for charging phones, operating radios and TVs and also low power computing devices such as laptops.

The output power is mostly DC but a plug-in separate inverter is sometimes used to operate specific AC appliance like a TV on the system. Some companies have recently incorporated a small inverter in the controller that provides AC power for some AC appliances. The Solectric300 and Solectric600 are a good example of a dual output systems.

Typical CSHS comes with one solar panel of between 50 and 200W. The majority are however less that 100Wp. They power between 4 and 10 lights. They also incorporate DC charging for mobile phones. At the higher power end, they incorporate a socket for powering radios, TVs and media players (DVDs and MP3). They provide lighting for between 4 and 8 hours per full day charge. Most of them use LED lamps. They provide 12V DC power but the majority do also have a separate inverter of between 150 to 300W that provides AC for operating specific appliances.

These systems are for market for the higher income households in rural areas.
Although some dealers have developed standard packages, the greater number of CSHS are customized to the needs of a customer.

iii) Prices

The prices for CSHS vary between KShs 400 and 1050 per Wp. The average price is Kshs 762 per Wp. The average system capacity is 92 Wp.

iv) CSHS Customers

The major CSHS customers are private individuals followed by non-governmental organizations and development partners. During the survey, 61 of the companies indicated that private individuals are the major buyers of CSHS followed by NGOs and development partners at 15%. Governments institutions, county and national, came third at a combined 15%.

7.1.2.3 Installed Capacity of SHS

No company responded to the survey question relating to number and capacity of installed systems. This makes quite difficult to estimate.

Using lighting Africa figures and assuming 30% of their reported sales were the packaged kits, then 1.3 million ISHS have been installed through that programme alone. This translates to 14 MWp of PV capacity.

Using the finding by KIHBS 2016 that 14.1% of Kenyan households utilize solar for lighting and that there are 8.77 million households in Kenya. Then 1.24 million households are using solar PV meaning there were at least 1.24 million PV systems in use in households by 2015. Assuming 50% of these are CSHS outside the lighting Africa programme, then we have about 600,000 such systems. At the average 13Wp per system, then we have 8 MWp as the installed capacity.

These combined results in a rough estimate of about 20 MWp of installed SHS capacity.

7.1.3 Stand-Alone PV systems

Stand-alone systems (SSPS) are custom-designed to satisfy energy and power demands for specified loads. These systems are mainly for institutions such as schools and health centres. They may also be for specialized applications such as powering base and repeater stations for telecommunication, cathodic protection for steel structures and other remote area applications. These systems may also be operated in hybrid modes with other power generators such as wind or diesel generators.

i) Brands in the market

These are customized systems and are put together by most major distributors, dealers and installers. They therefore do not carry specific brand names.

ii) Design characteristics

These systems are characterized by their capacities typically exceeding 200W. The highest capacity installation reported by companies was 2080 Watts. The majority of the systems are in the 200W to 1000W range. Almost all of them provide AC power output.

iii) Prices

The prices for SSPS vary between KShs 200 and 500 per Wp. The average price is Kshs 360.00 per Wp. The average system capacity is 350Wp.

iv) Installed capacity

This market segment has been in existence for a long time but gained traction in 2006 when the Government through the Ministry of Energy commenced a PV electrification initiative to equip public institutions such as schools, health centres, administration centres, etc., far from the grid with PV systems for lighting and basic power for operating entertainment electronics (TVs, music systems) and laboratory and other learning equipment. This initiative was escalated in year 2013 when the primary schoolôs laptop project was launched. It became necessary to install PV in all primary schools that are not connected to the grid to enable primary school beginners to start digital learning using laptops.

Whereas there are other private institutions and corporations who have a need and do purchase these high capacity systems, the Ministry of Energy and the Rural Electrification Agency, have been the main customer for these types of systems.

Between 2006 and 2016, the MoE had installed PV in 1337 public institutions mainly schools and health centres. The total installed capacity during the period by MoE was 2.85MW. REA on its part as of 2016 had installed PV in 4450 primary schools for the laptop for schools project. Each system had a capacity of 1680W. This program alone saw installation of 7.48MW of PV in 3 years.

The installed capacity from national government supported programme as of 2016 was therefore 10.33MWpk.

The above systems were installed by contracted companies. During the survey, we asked businesses to provide data on this range of PV systems particularly on the capacities and number of installed systems. The four companies that responded had together done 167 systems in year 2017 with a total installed capacity of 39.5 kWp. Two companies indicated that the client was REA which means their systems (110) were already included in the Government installed systems.

Private institutions and individuals are the major buyers of stand-alone PV systems, according to 50% of the companies interviewed. They could account for capacity roughly equal or larger that the government installations. This implies that another 10MWp or above of PV would have been installed in the country by private individuals and institutions.

Based on above assumptions, the estimated total capacity by market segment would be 20 MWp.

v) Stand-Alone PV systems customers

The major customers for SSPV private individuals followed by the national government. NGOs and development partners come third. During the survey, 50% of the companies who responded indicated that private individuals and institutions are the major buyers of SSPV followed by the national government institutions at 30%. He remaining comprised of NGOs and private institutions.

7.1.4 Solar Street Lighting Systems

Solar street lights have been around for a while but major interest was aroused by the installation of solar street lights on parliament road and Harambee Avenue by MoE in year 2010 for demonstration purposes. Since then county governments in particular and some corporations have adopted solar street lighting even when they are connected to the national grid. It is not uncommon to find solar street lights outside commercial buildings such as supermarkets.

i) Brands in the market

PV dealers have put together standard street-lighting systems but these have not been promoted as separate brands, other than perhaps the name of the company.

ii) Design characteristics

Street lighting systems are designed to provide lighting for 10 to 12 hours daily, all year round. The typical installed capacity range is 20Wpk to 80Wpk but lower and higher capacities are available. This range enjoys about 80% prevalence in the market. They all are DC for lighting only. They power both LED and CFL lamps. In some caes, CCTV security cameras are included.

iii) Prices

Based on the survey findings, the prices for SSL vary between KShs 400 and 1100 per Wp. The average price is KShs 876.00 per Wp. The average system capacity is 48Wp.

iv) Installed capacity

Solar street/security lighting systems (SSLS) have been adopted by county governments and even corporates for area lighting.

The survey established that 31 counties have adopted solar street lighting. Together they have installed a total of 12561 SSLS. Mandera, Nyamira and Turkana lead the pack with each having installed 1854, 1202 and 930 respectively.

At an average of 48Wp per system, the installed capacity by county governments is 603 kWp.

v) Street lighting Customers

The customers for solar street lights are mainly county governments and companies mainly commercial premises such as supermarkets. To date 31 counties out of the 47 have adopted solar street lights.

7.1.5 Solar Pumps

i) Brands in the marker

Two major brands, Grundfos and Lorentz dominate the local market. The other available brands are Shurflo (USA), Ennos Sunlight (Switzerland), Vacon from Danfoss and Hobertek from Hober (China), Dayliff and Powermik (China).

ii) Design and performance Characteristics

Both surface and borehole pumps are available in the market. Some are designed to be DC operated and others are AC operated so they come with appropriate Inverters and or system controllers.

Both positive displacement and centrifugal types are available in the market. The pumping heads for typical pumps range between 10m and 250m. Pumps are available for up to 400m head. The flow rates vary but typical pumps can deliver up to 90 M^3/hr at the lower pumping heads. The flow rate is determined by the PV power, pumping head and pump type. Both induction and brushless DC motors are used to operate the pumps.

iii) Prices

The typical pumping head varies between 10 and 200 metres. The flow rates vary between 1m^3/hr to 30 m^3/h. The typical power rating ranges between 300W and 10kW.

Solar pumping systems prices vary between 80 Kshs/Wp to 250 KShs/Wp. This depends so much on head and flow requirement and systems and includes solar array, Inverters and pumps, piping, cables, and installation. The average price for borehole complete systems is 200 kShs/Wp. A system for the solar generator only costs an average of 150 KShs/Wp.
The above price are based on prices provided by three major solar pumping service providers for systems with an average flow late of 9m^3/hour at 150m head for a fully installed and commissioned borehole system. The choice of 150m head and flow was based on assessment of average borehole yields and pumping heads of 400 boreholes spread across 6 counties based in coast, eastern, northern, rift valley and north-eastern parts of the country.

iv) Installed capacity

The few companies who provided some installation data have collectively installed a total of 6500 solar pumps between 2014 and 2017. The pump capacities vary between 300 and 5000 Wp with over 90% being 1000 Wp. The 6500 pumping systems have a total installed PV pumping capacity of 12 MWp. At least one of the companies that provided data is a major player.

Considering that that there are other players in the market and that there were systems that were sold earlier than 2014. The installed capacity to date is certainly much higher than what has been gathered by the survey. A conservative estimate would easily triple the reported capacity.

I rough estimate would put it at 10,000 systems and the total PV installed capacity at 20 MWpk.

v) Major solar pumping customers

Private individuals and institutions followed by NGOs and Development partners are the main customers of PV solar pumps. From the survey, private individuals and institutions are the main customers for 56% of the companies followed by development partners and NGOs at 33%. Government institutions come last.

7.1.6 Solar PV Mini-grids

Mini-grid solar systems (MGS) are high capacity, custom-designed systems to satisfy energy and power demands for a group of consumers. The investor recoups their investment returns over a period of time through the sale of electricity to the connected customers. These systems usually are operated in hybrid modes with other power generators such as wind or diesel generators and storage batteries are at times included in a number of them to enhance quality, adequacy and reliability of supply.

i) Brands in the market

These are customized systems and are put together by major distributors, dealers and installers. They therefore do not carry specific brand names other than perhaps the system integrator.

ii) Design characteristics

These systems are characterized by their capacities typically exceeding 1000W. The highest capacity installation reported by companies was 2080 Watts. The majority of the systems are between 10 and 80kW. All the systems provide single phase or 3-phase AC power output which is fed into a local distribution system, usually low to medium voltage overhead lines.

iii) Prices

Based on recent prices obtained from REA, the prices for minigrids with diesel generator back and batteries vary between KShs 600 and 800 per Wp. The average price is Kshs 740.00

per Wp. The generator adds about 10% to the system cost. Therefore the average price would be 670 KShs/Wp for a minigrid with battery storage.

iv) Installed PV mini-grids capacity

Solar mini-grids is a recent development in Kenya and the main driver for mini-grids installation has been the government.

The Government through Kenya Power and Lighting Company (KPLC) has been operating diesel-powered minigrids in remote county urban centres (formerly district or provincial headquarters) for a long time. To reduce the operating fuel cost of these mini-grids, it was decided to incorporate either wind or solar into the generation mix to operate in hybrid modes.

According to Eng. Gichungi [17], the government through REA/Ministry of Energy/KPLC had installed/hybridized with PV 10 mini-grid sites as of December 2017. The combined installed capacity at these 10 sites was 700kWp. Among the most recent systems, the smallest system capacity was 10kWpk and the largest was 80kWp. The single largest system of 330kWp was installed way back in 1979 in Mandera. REA has been continuing with development of mini-grids and 28 such sites were planned for completion by the end of 2018. Each site will have a 60kWp PV system operating in hybrid-mode with a Diesel Generator. Todate seven have been completed adding 420 kWp of PV minigrid capacity. The remaining are expected to be operational by year end and will add 1200 kWp.

Private investors and NGOs/Development partners have also been promoting and developing PV mini-grids. Most of these have been developed over the last 5 years. Todate about 20 private investorsô developed minig-rids with a total installed capacity of 200kWp are in operation. Interestingly, some mini-grids are operating in urban centres already connected to the grid, probably due to poor reliability of grid power.

The public and private sector installed capacities above make the total installed PV and operational mini-grid capacity 1.32 MWp. These installations may not be the only ones in the country but those that are not yet mapped cannot significantly alter the total installed capacity.

v) PV Mini-grid systems customers

The national government institutions (KPLC, REA, Ministry of Energy) followed by private investors and NGOs/development partners are the main customers. During the survey, 60% of the companies who responded to this indicated that national government institutions were the major customers followed by private individuals at 30%. The remaining comprised of county governments and NGOs.

7.1.7 Grid-connected systems

Grid-connected systems have recently hit the market. These were facilitated by the feed-in tariffs mechanism developed in 2008 by the Government, allowing private investors to connect PV and other renewable energy generated power to the grid. This enables the PV system to feed the grid system with power and also the investor to utilize PV generated power if the investor is also a consumer.

i) Brands in the market

These are customized systems and are put together by major distributors and installers. They therefore do not carry specific brand names other than perhaps the system integrator.

ii) Design characteristics

These systems are characterized by their capacities high capacities. The highest capacity installation reported so far is 1MW. The system capacities for grid-connection are restricted to a minimum of 500kW. However, in these early stages, small systems of even 30kW have been connected. All the systems provide 3-phase AC power output which is fed into the national grid distribution system.

These systems rarely have battery storage.

iii) Prices

The prices for grid-connect systems vary widely. Based on figures cited by developers for two projects which are operational and were commissioned three to five years ago, the prices vary between KShs 400 and 600 per Wp. The average price was KShs 500.00 per Wp. According to the 2017 IRENAǿs report - Solar PV in Africa, Costs and Markets, the average weighted installed cost for 2017 was KShs 140 per Wp but varies between KShs 90 to KShs 500 per Wp.

iv) Installed capacity

These systems are fairly high power and very few have been installed. The well-known and widely publicized, because of their pioneering roles, are Strathmore University (600kW), UNEP h/q (500kW), Garden City (860kW). There are others which are small like SOS (60kW) village in Mombasa.

The survey stablished the existence of 13 grid-connected PV systems in Kenya with a total installed capacity of 5.83MW.

iv) Major customers for grid-connected PV systems

To date, private entities have been the major customers for grid-connected PV systems (GPV). These companies include manufacturing companies, flower farms, research institutions. Even though there is a power exchange between the grid and the PV system generator, the private investor does not get paid for any power that gets absorbed into the grid from the system at the moment. The incentive to invest is basically the need cut down on grid power costs through captive power generation.

The ultimate customer for grid-connected system is essentially the power distributor, especially in situations where the producer is an investor whose motivation is to sell power under a PPA. Currently, projects are under development that are primarily aimed at the utility purchase.

7.1.8 Total Installed PV capacity Estimate

A rough estimate of the national PV installed capacity would be the addition of the capacities by segment. The addition results in 80MW. This is conservative estimate.

7.2 PV systems performance

A well-designed system utilizing good quality PV components and accessories, which is properly installed and maintained performs well for a long time, hence meeting customer expectations.

Industry players including the Government, NGOs and development partners realized over 30 years ago that PV can competitively address the low power needs of people living in off-grid grid areas. So it could significantly contribute towards provision of electricity for lighting and power in these areas and also facilitate access to other services such as health, education, telecommunications etc, hence make significant contribution towards improving the standards of living of the rural communities.

In the late 990ǿs and early 2000, it was established that PV products getting into the country were of low quality and the overall performance of PV systems was poor. Furthermore, there was no policy, legal or regulatory framework to guide the development of the industry. Products and quality standards were non-existent. In year 2000, it was estimated that 60% of all solar home systems (SHS) installed in Kenya were performing very poorly and most of these did not work at all. Apart from being a disincentive to market development, poor products and systems quality and lack of a suitable regulatory framework created the perfect environment for customer exploitation and dumping by unscrupulous businesses.

The Government together with other stakeholders and industry players set out to address the challenges through development of PV standards and codes of practice. Training of PV technicians were encouraged and supported by donors including the World Bank, UNDP, GEF, etc. A renewable energy standards technical committee was created at KEBS to develop standards and codes of practice for PV and other Renewable energy technologies in 1999. A local industrial association was created. Training of technicians and PV practitioners, supported mainly by donors were undertaken.

By year 2004, the new energy policy recognized and pledged to support development of PV and other RE technologies development. A legal framework was included in the Energy Act, 2006. By year 2012, many PV standards and codes of practice were in place. PV Regulations were gazette and mechanisms were created for managed and orderly development of the PV industry including licensing, registration, training and certification of technicians.

This survey set out to appraise the performance of PV systems generally by asking the PV suppliers/installers and a few institutional customers how the performance of PV systems is perceived by the industry. 50 public institutions were selected to participate in the performance survey. Out of these only 29 public institutions responded to the questionnaire.

Business enterprises were interviewed about systems performance in an addition to the public institutions.

In both cases the interviewees were asked to express their opinions about the performance of PV systems being utilized by themselves or from feedback received from their customers by ranking the system performances in a scale of good, satisfactory or poor. The results are shown in table 7.1

Table 7.1: PV Systems performance rating by end-users and suppliers

PV System performance rating	**Percentage No. of End-Users**	**Percentage No. Suppliers/Installers**
Good	48.3	80
Satisfactory	34.5	20
Poor	17.2	0

It is observed that over 52% of the of end-users who answered satisfactory or poor have issues with the systems performance. Even suppliers acknowledge that some systems are not performing well based on feedback from their clients.

The causes of poor performance were investigated. The interviewees were asked to indicate likely cause of failure amongst component failure, poor installation, lack of maintenance, system misuse/overuse and any other likely cause they may have experienced. The results are provided in table 7.2.

Table 7.2: Cause of poor PV Systems performance rating by end-users and suppliers

Cause of PV System's poor performance	**Percentage No. of End-Users**	**Percentage No. Suppliers/Installers**
Component failure	45	4
Lack of maintenance	48	22
Poor installation	21	22
Misuse/overuse	3.5	74

It is observed that lack of maintenance is a major issue to both end-users and suppliers. The same with poor installation. Whereas end-users do not think they misuse/overuse the systems, suppliers are unanimous that customers do not use systems as per design specification tending to overuse them. The divergence on component failure is rather surprising.

Components reliability was assessed. The interviewees were asked to rank the level of failure contribution of each of the main PV components to the system failures. The results are shown in table 7.3 and 7.4.

Table 7.3: Components responsible for failures ï responses by end-users

Solar Component	**No. of suppliers with most failures**	**No. of suppliers with few failures**	**No. of suppliers with least/no failures**
Solar Panel	5%	0%	95%
Solar battery	22%	44%	33%

Charge Controller	24%	18%	59%
Inverter	33%	17%	50%
Lights	0%	29%	71%

Table 7.4: Components responsible for failures ï responses by suppliers

Solar Component	No. of suppliers with most failures	No. of suppliers with few failures	No. of suppliers with least/no failures
Solar Panel	7%	21%	72%
Solar battery	21%	24%	55%
Charge Controller	17%	14%	69%
Inverter	24%	28%	48%
Lights	21%	24%	55%

It is observed that both users and suppliers agree that the solar panel is the most reliable component of the PV systems. The battery is the most unreliable and causes most failures followed by the Inverter. The charge controller is the most reliable electronic components of PV systems. End-users do not have issues with lights.

In conclusion, about 64% of suppliers and end-users state that the performance of PV systems is good and 27% state that the performance is satisfactory. This is a clear endorsement of PV as an electrical energy alternative source for the country. Lack of maintenance and battery problems were the main causes of poor performance. These should be targeted for corrective actions.

8. LEVELIZED COST OF SHS AND PV WATER PUMPING

8.1 Levelized Cost Evaluation and Assumptions

Levelized cost is an economic assessment of the cost of energy generating system including all costs over its lifetime taking into consideration the initial investment, operational and maintenance costs, fuel cost and the cost of capital. It is the breakeven cost of an energy project.

In this survey, it is intended to determine the levelized cost of energy generated by PV systems specifically the SHS and water pumping (SWP) systems. These two have demonstrated that they have and will continue to have a great impact in Kenya on electricity and water access to rural populations.

The general equation for calculating the levelized cost of energy is provided hereunder.

$$\mathrm{LCOE} = \frac{\text{Overnight Cost of Capital} * \text{Capital Recovery Factor} + \text{Fixed O\&M}}{8760 * \text{Capacity Factor}} + (Fuel\ Cost * heat\ Rate) + Variable\ O\&M$$

Where:

i) Overnight cost of capital is initial investment cost in KShs//kW of the energy system

ii) Capital Recovery Factor CRF is computed from:

$$CRF = \frac{\{i(1+i)^n\}}{\{\left((1+i)^n\right)-1\}}$$

iii) Fixed O&M is the annual fixed operations and maintenance cost per kW in KShs/kW-year

iv) Variable O&M is the annual variable operations and maintenance cost per kW in KShs/kW-year

v) 8760 is the number of hours in a year

vi) Fuel Cost is fuel used as would happen if a diesel-PV hybrid system were being considered

vii) *i* is the discount rate and *n* is the useful service life of the energy system

To work out the levelized cost of energy of the PV systems, all the above parameters need to be determined, for both the SHS and solar Water Pumping (SWP).

Initial investment

These were obtained from the market and the average costs determined per Wp in the preceding chapter.

For the SHS, the average price of the average system capacity of 13Wpk was taken as the initial investment cost equivalent to Kshs. 14690. The average irradiation for Kenya of 5.5 kWh/m²/day was assumed.

For Solar pumps, the average system cost was 150 KShs/Wp which is equivalent to 150,000 Kshs/kWp. The average irradiation for Kenya of 5.5 kWh/m²/day was assumed.

Fuel cost

These systems are fully PV powered so this is zero.

Discount rate

A simplistic approach shall be used to determine the discount rate. The target SHS and water pumps purchasers usually buy cash (equity) or may be financed (debt) through Savings and credit societies (SACCOs), higher purchase traders, lease to own like the PAYGO, personal loans from banks. In determining the discount rate, the various interest rates were considered:

- Commercial banks average lending rate for 2017 = 13.64% p.a.
- Average Interest rates on bank deposits 2017= 8.22% p.a.
- CBR Rate for 2017 = 10% p.a.
- Saccos lending rate = 12% p.a.
- The least cost power development plan 2017 reference discount rate is 12%.

Since these are essentially energy projects, and for ease of comparison between other energy sources, and the fact that the loans are priced at about the same rate, a 12% discount rate shall be used for analysis. So i=12%.

Useful service life

Almost all PV modules in the market are crystalline silicon and come with a guarantee period of 20 years. So, the system service life shall be assumed to be 20 years. So n=20.

Fixed and Variable O&M costs

For SHS, the O&M costs envisaged include cleaning the modules very often if in really dusty locations or once per month. This does not require a skilled technician to do. However preventive maintenance by a skilled technician is necessary, twice a year, to keep the system in good working condition. A semi-skilled technician can do this service on a system in half a day but to factor in travel time, we will assume a full day work.

The solar batteries incorporated in the SHS will not last as long as the PV module. The deep-cycle lead acid type, commonly used with SHS, if well managed (shallow daily discharge cycles, avoided deep discharges, very well controlled charging) and maintained may last up to 5 years. Lithium-Ion batteries, very good cycling ability meaning smaller capacity can be used, are also becoming quite common with ISHS and local suppliers are giving them service life of 5 years. For the purposes of this analysis, it will be assumed that they are well used and will need replacement after 5 years. Charge controllers will, if well maintained serve without problems for about 10 years.

As for lamps used in the SHS, there are CFLs, LEDs and Linear fluorescents. The lower power SHSs are almost all using LED. CFLs and linear fluorescent tube are also in use but not common. The service life of LEDs is said to be above 25000 hours and can get to 50,000 hours. For the purposes of this analysis, the LED lamps shall be used for between 3 and 4 hours per day hence they should last 20 years, the service life of the PV system.

As a system is used, some failures and repairs may occur requiring attendance by a qualified electrician. Some component may fail requiring replacement.

Variable costs are those costs that vary with the amount of energy generated. The SHS by its very nature of operation does not have these costs.

From discussions with practitioners during the survey, it was determined that an amount equal to 10 percentage of the initial system cost per annum would adequately cater for maintenance cost for SHS. Batteries will require replacement every 5 years and controllers every 10th year. For the average SHS of 13W, batteries account for between 20% and 30% of SHS cost, according to studies by Lighting Africa programme. The average 25% of the system initial cost shall be assumed for cost of battery replacements. The 10% annual O&M costs shall be assumed to be sufficient to cater for charge controller replacement in the 10th year.

Solar pumps only need solar modules, system controller and/or Inverters and pumps/motor units. The discussion for SHS above is also relevant and applies for PV modules in water pumping. The system controller and inverters are electronics similar to charge controllers, so the discussion on charge controllers applies to them too. Pumps and motors are proven technologies and with proper management, 10 years life easily attained. Hence, only system controllers and pumps will need replacement after 10 years. However, including pumps and motors would not be desirable for this analysis since it will distort comparison with alternatives which is the main use of levelized costs. Consequently, cost of pumps and motors shall be excluded from the analysis.

As is the case for SHS, solar pumping systems require twice a year preventive maintenance visits by skilled technicians. Solar pumps need a semi-skilled operator to monitor operation and undertake frequent cleaning of panels to maintain water output levels. Some component or system failures may occur requiring attendance by a qualified electrician. Some components may fail requiring replacement. Variable costs as stated earlier are dependent on amount of energy generated but solar pumps output is limited by insolation, hence variable costs are not applicable. Based on discussions with suppliers during the survey, it was determined that an amount equal to 10 percentage of the initial system cost per annum would adequately cater for operation and maintenance cost for SWP. The solar pumping systems will require replacement of system controllers and/or inverters in the 10th year. These cost about 20% of total system costs and replacement costs for them in year 10 shall be assumed to be equal to 20% of the initial system cost.

So, the O&M costs are:

SHS: Fixed annual O&M costs at 10% of initial system cost annually and 25% of the initial system cost for battery replacement every 5 years.

Solar Pumps: Fixed O&M costs at 10% of initial system cost annually and 20% of the initial system cost for replacement of system controllers and Inverters in the 10 year.

Capacity Factor

Insolation in Kenya varies between locations but the average national irradiation is 5.5 kWh/M²/day. This means that out of 24-hour day, in an ideal situation, the PV would generate maximum output for only 5.5 hours resulting in an ideal capacity factor of 22.9%.

However, considering dust degradation of module output, systems losses due to high ambient temperature effects on module output, losses in cables, efficiency losses in charge controllers and batteries in SHS and in system controllers and/or inverters for water pumping, the output will certainly be lower than the ideal condition above reducing significantly the capacity factor. Taking these into account, the pumping system capacity would be reduced by about 20% and the SHS capacity by about 30%. This leads to capacity factors being approximately:

SHS capacity factor = 16%

SWP capacity factor = 18%.

Inflation, financing, depreciation, taxation and O&M escalation rates

For the purposes of this analysis, these costs have been assumed to be non-existent. Tis essentially leads to a break-even levelized cost of the systems.

8.2 Levelized cost of SHS

The parameters described in the preceding section were applied to the LCOE equation.

The levelized cost of energy for SHS = 146 KShs/kWh.

8.3. Levelized cost for PV generated energy for water pumping.

The parameters described in section 8.1 were applied to the LCOE equation.

The levelized cost of energy for SWP = 23 KShs/kWh.

9. CHALLENGES AND BARRIERS IN ADOPTION OF PV IN KENYA

The development of the local solar PV market has encountered and continues to experience some challenges. The survey set out to determine the challenges and barriers the industry is facing. The survey further sought proposals on how the challenges should be addressed.

9.1 Challenges and barriers

Key industry players were interviewed. They were asked to state any challenges and barriers that may be hindering the adoption of PV products in Kenya.

Over 70 responses were received. The listed challenges were classified into seven broad categories, namely taxation, high cost of PV, consumer awareness, financing, policy and regulation, enforcement of standards and regulations and skills.

The frequency of each of the above responses amongst the respondents was analysed and the results are illustrated in figure 9.1.

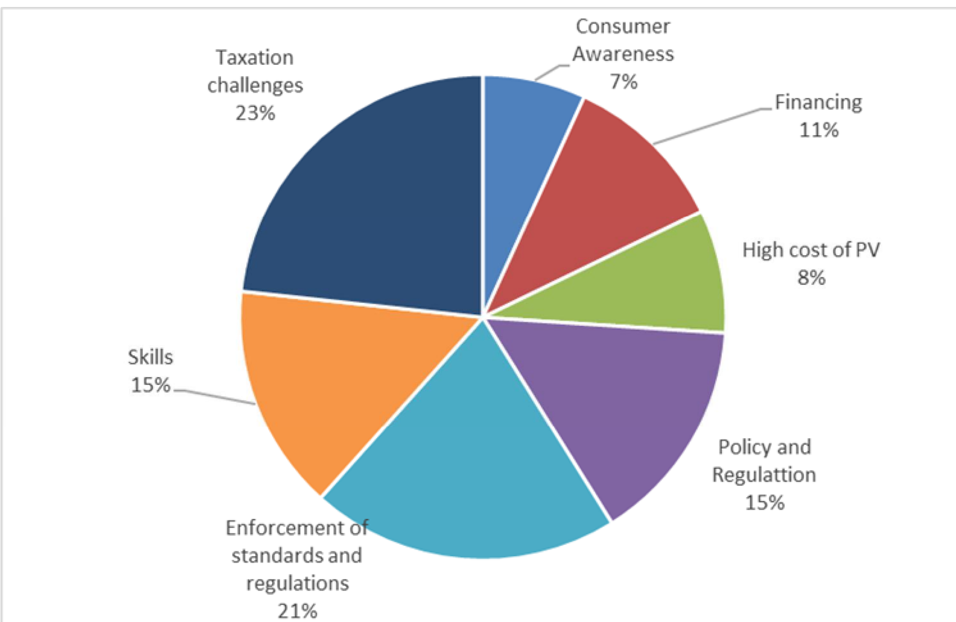

Figure 9.1: Frequency of challenges and barriers hindering PV adoption in Kenya

Taxation challenges

Taxation challenges cited include: -

- Lack of clarity of taxation of imported PV products. There is a lot of confusion on how to apply import duties and taxes on PV equipment. More so when PV modules include BOS components
- Taxation of PV BOS components and accessories
- Taxation on minigrids power

Almost all respondentÕs main complaint was the application of import duties and taxes on PV equipment and accessories and lack of clarity on taxation especially because of different interpretation of PV systems and BOS components by KRA, KEBS and ERC when it comes to assessing taxes. Whereas PV modules and solar cells are zero rated, payment of duty and VAT on all other BOS components (solar batteries, Inverters, Charge controllers, lamps) is dependent on how they are brought into the country and interpretation by the KRA personnel. KRA at times insists they are separate items and they should be taxed separately. In other cases, they are interpreted as part of unassembled PV modules.

The other major issue is levying of duties and taxes on PV BOS components and accessories. This most feel should be abolished altogether for PV BOS and PV generated power from minigrids.

Enforcement of standards and regulations challenges

Respondents main complaint was that there is poor enforcement of standards and regulations already in place. This has led to:

- Poorly installed PV systems that do not perform. If the code of practice was enforced, then this would not be the case.
- A lot of counterfeit PV products in the market. If standards were strictly enforced, then counterfeits would be minimised.
- Poor quality of products getting into the market ÒespeciallyfromtheEastÓ to quote one respondent.
- Poor quality control aided by lack of monitoring and quality assurance framework supported by a local testing laboratory.

The general consensus is that poor enforcement of standards and regulations already in place and quality control and market monitoring will minimise poor and non-performing PV installations, eliminate counterfeit products in the market, and ensure that products and services that do not meet standards do not get into the market.

Policy challenges

The policy challenges cited include:

- Inadequate regulatory framework for pico-solar and SHS
- Lack of policy captive power
- Lack of policy on net metering and wheeling
- Lack of standards on pico solar
- Lack of clarity on licensing
- Poor data gathering especially county specific data
- Preferential subsidies on minigrids to KPLC but not applicable to private developers
- Lack of Incentives
- Lack of policy on PV mini-grids

Skills Challenges

In as far as skills are concerned, the industry cited lack of adequate and competent PV personnel to service the industry across all levels of PV system including large SHS, hybrids, grid-connect and engineer, procure and construct kind of PV works. It was also felt that there are inadequate skills in government agencies to professionally tackle policy and regulatory issues. It was also felt that skills are not available in off-grid areas and that existing curriculum for training and certifying PV technicians needs to be reviewed.

To gain greater insight into the skills availability and adequacy, PV business and technical skills were grouped into five broad categories and businesses were asked to indicate the whether the skills are available in the industry and whether they are adequate. Skill adequacy means that the sector has enough supply of trained and competent personnel to provide professional service in the subject field.

Table 9.1: PV skills availability and adequacy assessment results.

Skill Description	**No. of respondents who said Skills are available (%)**	**No. of respondents who said Skills are adequate (%)**
Business modeling	*69*	*25*
Feasibility studies and project evaluation	100	40
Raising finance and risk analysis and management	86	55
Design, installation and operation of stand -alone PV systems	100	69
Design, installation and operation of mini-grid and grid-connected PV systems	86	75

The main observation from the above is that skills at all levels are available to a great extent. However, they are not adequate meaning that the industry does not have enough supply of trained and competent personnel to provide professional PV business and technical services to the market. Whereas all the skill levels are affected, business skills are most lacking.

Financing Challenges

Financing is a significant barrier according to the industry. Respondents did not elaborate on this but many mentioned lack of project finances, working capital and funds for PV customers to acquire PV systems and services.

To gain a better understanding of financing challenges the industry is facing, business enterprises were asked to indicate their source of finance for businesses operations. They were asked to indicate whether they used cash which is internally generated revenue, bank loans, supplier credit facilities, other financial institutions like Saccos and MFIs, or other sources. The results are shown in figure 9.2.

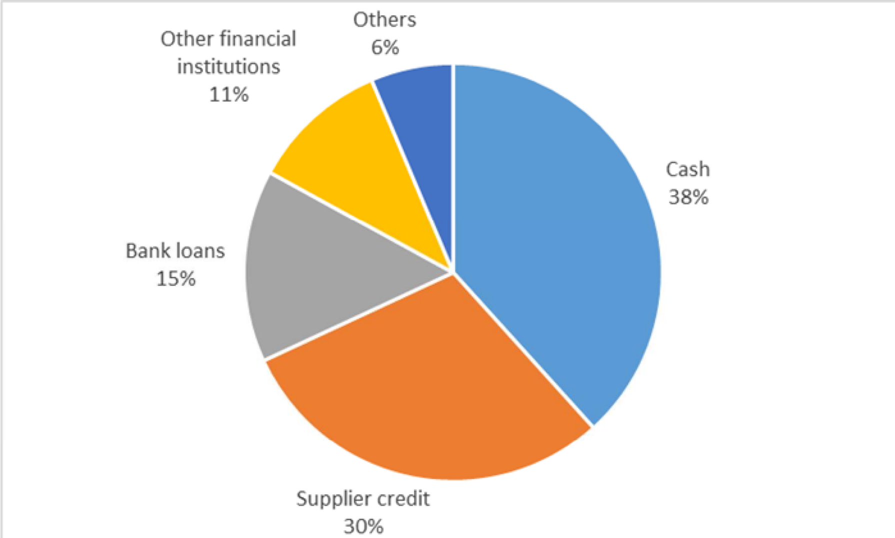

Figure 9.2: Sources of finance for PV businesses in Kenya

It is observed that about 60% of PV businesses require some form of financing for their operations. This is a high number and is indeed a challenge.

It is observed that internally generated revenue (cash) and supplier credits are key financing sources for PV businesses. Supplier credits will normally be 30 days but can go up to 90 days. Considering the time period, businesses must be able to turn-around their stocks fairly rapidly to service supplier debts. Furthermore, they may not be able to procure substantial stocks to benefit significantly from economies of scale associated with huge stocks shipment.

Bank loans and loans from other financial institutions like micro-finance institutions provide a significant amount of funding to PV companies.

Preference of cash and supplier credits is understandable because they have no direct costs while loans have direct costs.

High Cost of PV challenges

This is about affordability. It is really about financing and should easily fit into the financing described above but is being discussed separately because its about financing the PV system purchaser or end-user especially for SHS.

To have a feel about how customers finance their PV systems, we asked companies to give us an indication of the sources of finance for their customers to procure PV systems.

The companies were asked to indicate how, from their own experience, their customers finance their systems, whether they use cash, bank loans, supplier credit facilities, hire purchase, other financial institutions like Saccos and MFIs, or other sources. The results are shown in figure 9.3.

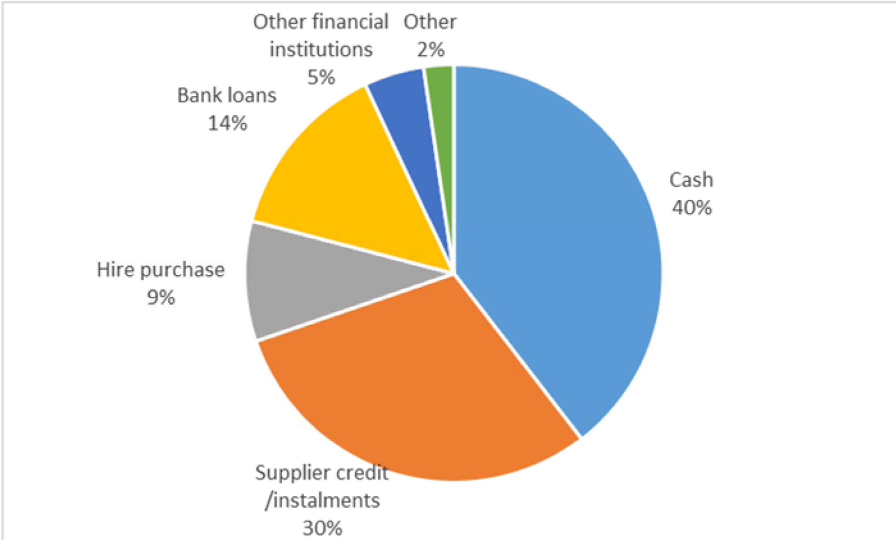

Figure 9.3: Sources of finance for PV customers

For PV purchasers especially SHS supplier credits is in form of instalments. A customer pays the full price of the system in instalments and the system is only installed once the purchase price is fully paid. This form attracts no interest. In hire higher purchase, the customer acquires the system and pays as they use. Itõs a form of lease-to-own kind of arrangement.

It is observed that about 60% of PV customers require some form of financing. This is a high number and is indeed a challenge.

The new energy policy ï National energy and petroleum policy, 2017 - lists the main challenges facing the solar energy sector:

- Un-coordinated approach in policy implementation and promotion of solar energy projects;
- High upfront capital cost for plant and equipment.
- Weak enforcement of standards and regulations.
- Rampant theft of solar photovoltaic panels, which discourages the installation.
- Lack of awareness on the potential, opportunities and economic benefits offered by solar technologies.
- Proliferation of sub-standard solar energy technologies and equipment

The challenges facing the feed-in tariffs are also identified in the policy and include:

- Insufficient data and analytical tools to inform the level of tariffs for different technologies
- Lack of awareness on FiT among the potential investors.
- No clear guidelines on PPA negotiations.
- Inadequate technical and financial capacity.
- Tariffs charged do not generate sufficient revenues to cover capital, operation and maintenance costs of the projects.

In general, the survey findings confirm to a large extent the challenges identified in the new policy whose implementation has just started.

9.2 Industry Proposals for addressing the challenges and barriers

The stakeholders surveyed were asked to propose how the identified challenges and barriers should be addressed. The proposals received are summarized hereunder:

- Appropriate policies, standards and regulations should be developed to guide development of emerging market segments like pico-solar, mini-grid, grid-connect with captive power component, etc.
- Standards and regulations should be enforced to ensure that consumers get only good quality products and services at all levels along the supply chain.
- Market monitoring and surveillance should be enhanced
- There are skills gaps in the market and skills enhancement initiative needs to be put in place
- Financing is a challenge and appropriate mechanisms should be developed for various players along the supply chain
- Cost of PV systems is high and ways should be explored to make PV systems more affordable
- Taxation of PV systems, BOS components and accessories is ambiguous currently, leading to different interpretations and taxation levels and should be reviewed to clarify.
- Taxation of PV systems and components, at all levels should be reviewed with a view to removing taxation altogether
- Counterfeits are getting into the market and a strategy to eliminate them should be developed
- Incentives should be considered to accelerate market development.

In conclusion, the industry feels that existing policies need to be reviewed and new policies need to be developed to cater for emerging market segments like pico-solar, private mini-grids, small capacity grid-connected systems and incentives. This will streamline the operations of the PV sector and enhance PV uptake.

The industry is emphatic that taxation, high cost of PV, consumer awareness, financing, policy and regulation, enforcement of standards and regulations and skills availability and adequacy are the main challenges and barriers hindering the growth rapid growth of the industry. Taxation and enforcement of standards are the biggest challenges followed by lack of adequate skills. Financing and consumer awareness challenges are still significant just as is awareness creation amongst consumers.

Government agencies are responsible for policy, taxation and enforcement of standards, which combined form 59% of the challenges pointed out by the industry. It is therefore clear that government action is the one single entity that can rapidly transform the PV industry in Kenya.

10 SOLAR ENERGY POLICIES AND STRATEGIES

10.1 Local situation

10.1.1 Existing Energy Policies and strategies

The current national energy policy was developed in 2004. Entitled "Sessional Paper Number 4 of 2004 on Energy", the policy laid down the framework upon which quality, cost-effective, affordable, adequate and sustainable energy services are to be availed to the economy over the period 2004-2024.

In the policy document, the Government undertook to:

- Expand and upgrade the energy infrastructure;
- Ensure security of supply through diversification of sources and mixes in a cost-effective manner;
- Promote energy efficiency and conservation;
- Enhance economic competitiveness and efficiency in energy production, supply and delivery;
- Formulate enabling legal, regulatory and institutional frameworks;
- Promote public– private partnerships in the provision of clean energy services.

Solar PV was not explicitly addressed in the policy but together with other technology under renewable energy. As far as renewable energy is concerned, the policy commits the Government to:

i) Promote the development and widespread utilization of renewable energy technologies to widen access to clean, sustainable, affordable, reliable and secure energy services for national development while protecting the environment.
ii) Encourage and promote private sector initiatives in the development and expansion of the renewable energy markets.
iii) Allocate resources to complement self-help groups and private sector efforts in rural energy supplies.

Various strategies were proposed to accomplish the above:

- Designing incentive packages to promote private sector investments in renewable energy and other off-grid generation.
- Providing requisite support for research and development in emerging technologies like cogeneration and wind energy generation.
- Encouraging and promoting private sector initiatives in the development and expansion of the renewable energy markets.
- State financing and implementation of indigenous energy resources assessment and feasibility studies
- Formulation and enforcement of standards and codes of practice on renewable energy technologies to safeguard consumer interests.
- Allocation of resources to complement self-help groups and private sector efforts in rural energy supplies.

- Packaging and dissemination of information on renewable energy systems to create investor and consumer awareness
- Promoting vertically integrated mini-grid systems for rural electrification using renewable energy technologies even in areas where licences have been issued to public electricity supplier.
- To amend building by-laws under Local Government Act to make it mandatory in urban areas to include hot water systems in building designs.
- Promote research and development and demonstration of the manufacture of cost-effective renewable energy technologies;
- Promote development of appropriate local capacity for manufacture, installation, maintenance and operation of basic renewable technologies.
- Promoting development and widespread utilization for renewable energy technologies which are yet to reach commercialisation;
- Allowing duty free importation of renewable energy hardware to promote widespread usage;
- Providing tax incentives to producers of renewable energy technologies and related accessories to promote their widespread use
- Providing fiscal incentives to financial institutions to provide credit facilities for periods of 7 years to consumers and entrepreneurs
- Enabling renewable energy systems not exceeding 3MW or if operating in hybrid mode in which the oil-fired component does not exceed 30% of the total capacity to operate in any area of the country without any license, irrespective of any other existing distribution license;
- Making it mandatory for a licensed public electricity supplier operating in an area where power generation is being undertaken by parties other than those with agreements or arrangements with such public electricity supplier to buy such power on terms approved by the Energy Regulatory Commission (ERC). Preferential treatment shall be given to electricity generated from renewable energy.

The above renewable energy policy framework and strategies were well thought out, comprehensive and progressive and would, if fully implemented, transform the renewable energy sector including solar PV. Now that this policy is about to be replaced by the new policy, whose implementation is about to start, it is fitting to outline the status of implementation and registered successes in relation to solar PV only:

- Many PV standards have been developed including a code of regulations.
- Import duties and taxes on PV modules were abolished.
- Government commenced and continues to fund PV electrification of public institutions.
- Government commenced and continues to fund hybridization of Diesel Powered mini-grids with PV
- Government recently commenced establishment of new PV mini-grids for settlements in off-grid areas

- Feed-in- Tariffs policy was developed and is under implementation for PV generated electricity
- Private sector has been encouraged to enter the mini-grids market utilizing PV technology
- Training and certification framework was introduced for PV technicians
- PV regulations were introduced in 2012. These regulations put in place processes and procedures for proper conduct of business, creating order in the industry.

Comparing what the policy would have seen implemented and what has been achieved, it is clear that the main policy interventions which would truly have transformed the industry such as special incentives packages for off-grid mini-grids, tax incentives, fiscal incentives, tax holidays, were not implemented and that the implementation of the energy policies and strategies has been slow and faced a number challenges most to do with limited financial and technical capacities.

10.1.2 New energy policies and strategies on solar energy

The new energy policy ï National Energy and Petroleum Policy, 2017- whose implementation has just started, has identified the following policies and strategies to support solar energy technologies market development: -

i) Undertake awareness programs to promote the use of solar energy
ii) Enforce regulations and standards.
iii) Regular review of standards for solar energy technologies and equipment.
iv) Provide incentives to promote the local production and use of efficient solar systems.
v) Provide a framework for connection of electricity generated from solar energy to national and isolated grids, through direct sale or net metering
vi) Enhance penalties for theft and vandalism of solar systems.
vii) Support hybrid power generation systems involving solar and other energy sources to manage the effects caused by the intermittent nature and availability of solar energy.
viii) Roll out installation of solar PV systems in all the remaining public facilities in the off-grid areas
ix) Procure and distribute solar lanterns to light up rural, peri-urban and urban areas.
x) Undertake RD&D on solar technologies.

The feed-in-tariff policy is set to be reviewed under the new policy as it is seen as the key mechanism to encourage private sector to invest in renewable energy. The new FiTs strategies shall include:

i) Encouraging the private to develop potential sites to generate electricity for their own consumption and for export of any surplus to the national grid.
ii) Formulation and implementation of promotion campaigns to attract potential Investors.

iii) Periodic review and implementation of FIT policy.
iv) Undertaking periodic studies on the capital expenditures and operating costs of the different types of technologies and develop sufficient analytical tools to inform the level of tariffs for different technologies.
v) Development and regular review of model power purchase agreements for the various modes of generation.
vi) Provision of capacity building programs and financial assistance to community-based projects.
vii) Expanding the scope of FiT to include emerging technologies.

Good and progressive policies are by themselves not enough. They require total commitment and adequate financial and technical resources in a timely manner for their implementation. Perhaps its this realization that has influenced the new policies and strategies, which are few and do not require huge resources.

10.2 International Scene

In chapter 4, it was demonstrated that global PV market has grown exponentially over the last 20 years and the main growth drivers were the plummeting PV prices and incentive schemes by Governments.

It was also observed that developed and rich countries encouraged and supported the PV industry across the value chain ï from manufacture to end-use. At the end use level, these countries supported PV systems installations for grid connection. In developing countries in Asia and Africa however, the few countries that had support programmes initially targeted off-grid applications aimed at increasing access to basic electricity.

It was also shown that newly industrialized and developing countries have devised initiatives to support PV markets development. Over the last few years, China and India alone contributed over 50% of the new PV capacity installations in the world.

The main policy incentives that have been employed by governments to support investments in PV were listed:

- Feed-in Tariffs
- Direct subsidies or rebates
- Tax breaks
- Net-metering
- Self-consumption
- Energy auctions
- Trading of green certificates
- Regulations
- Electrification targets
- Quality Assurance frameworks

Feed in tariffs and direct subsidies and tax breaks have been most successful market support mechanisms for PV. Combined, they support 81% of the global PV markets.

A brief review of policies and strategies used in many successful PV markets was undertaken and a few cases are provided hereunder.

i) China

China is the largest PV market in the world currently and in 2016, its global market share was 46%. China has largely employed feed-in tariffs but differentiated by capacity, PV resource at site, subsidies and grants to targeted groups. Poor households get systems installed at no direct cost. Distributed generation get subsidies on generated energy. Building integrated PV get upfront subsidies and systems with a minimum 50kW benefit from capital premium.

ii) USA

USA is the second largest PV market in the world currently and in 2016, its global market share was 20%. In USA, various incentives are employed by different states. There are feed-in-tariffs, investment tax credits, grants and subsidies and infrastructure investments at federally assisted housing schemes.

iii) Australia

Feed-in tariffs, grants and subsidies are the key incentives that drive the Australian PV market.

iv) United Kingdom

UK was largest PV market in Europe in 2016. UK employs feed-in tariffs with both generation and export tariffs. You get paid for what you generate and what you export.

v) Cyprus

Subsidies and grants. Mandatory PV solar installation in new residential buildings

vi) India

Various measures by different states but mainly around feed-in-Tariff supported with accelerated depreciation, generation-based incentives, energy purchase obligations, etc.

vii) Kenya

Feed-in-tariff for 0.5MW and above capacity systems. Grants to public institutions for PV installations and direct funding for grid-connect and mini-grid systems. Tax exemption on PV modules only.

viii) Mauritius

Grants for grid connected systems for captive use.

ix) Algeria

Feed-in Tariffs main incentive scheme

x) Thailand

Feed-in tariffs main incentive for Thailand.

xi) Philippines

Feed tariffs and net-metering

The above few but very brief case studies show that feed in tariffs, subsidies and tax incentives are the most common PV market support mechanisms being employed by governments. This supports the finding that feed-in tariffs, subsidies and taxes have been most successful market support mechanisms for PV deployment globally.

10.3 Kenya PV policy analysis

The 2004 energy policy did not have a specific policy on solar PV technology. Instead it was lumped together with other technologies under ótother renewable energy technologies. The new energy policy (2017) has specific sections devoted to solar energy and PV in particular. This is a positive development.

A look at the policies and strategies for rapidly growing PV markets shows that feed-in-tariffs, subsidies and taxation have been very successful market development support mechanisms. Looking at the market segments globally, its observed that off-grid market is less than 1% of the global PV business. It is not therefore a surprise that grid-connected PV segment dominates the global market. This can to a great extent be attributed to the feed-in tariffs mechanisms.

10.3.1 Feed-in Tariff for PV

Kenyaôs current feed-in tariff policy for PV differentiates between off-grid, which really refers to PV systems that generate power for connection to an existing mini-grids or a new mini-grid and grid-connected PV systems. The tariffs are provided in Table 10.1

Table 10.1: Feed-in Tariff Structure for PV systems

PV Systems Description	Minimum Capacity (MW)	Maximum Capacity (MW)	Feed-in Tariff (US $/kWh)	Remarks
Grid Connected (Large Power)	10.1	40	0.12	12% escalable portion of the tariff. Cumulative maximum national capacity limit 200MW
Grid Connected (Small Power)	0.5	10	0.12	8% escalable portion of the tariff. Cumulative maximum capacity limit included in large power figure
Off-grid	0.5	10	0.20	8% escalable portion of the tariff. No capacity limit stated.

The main question is whether this tariff structure is suitable and adequate to support development of PV market in Kenya. The following are the major observations:

i) Both on-grid and off-grid have a minimum capacity set at 0.5MW. This capacity restriction locks out all other PV systems.

ii) The cumulative national capacity target is 200MW. This means only a few systems can be installed.

iii) The tariff does not consider captive power producers who may have excess capacity that can be fed into the grid.

iv) The tariffs are flat across the country. They do not consider the solar resource availability and intensity across geographical locations.

It is however observed that the new energy policy has undertaken to periodically review the FiTs policy. This is among the issues that should be considered a priority.

10.3.2 Subsidies and Taxation

Subsidies and tax incentives are the other two key policy strategies that have been highly successful internationally.

The 2004 policy included both. As far as taxation was concerned only import duties and taxes (VAT) on PV cells and modules was implemented. As far as subsidies are concerned, the government has been funding the installation of PV systems in public institutions over the last 12 years as part of rural electrification. The public institutions do not contribute anything, so these can be considered as grants. The government is also financing hybridization of existing diesel powered mini-grids and also establishing new PV-Diesel minigrids. The government has also started distributing free solar lanterns to selected populations.

The new policy commits to continue the above initiatives, which are great subsidies that supports the industry directly by creating more business. The new policy does not however mention any other fiscal or financial incentives to support the industry.

It is also observed that the subsidies only support only two market segments ï the solar lanterns and the stand-alone institutional market segments. The other 6 segments are not supported at all. This means the largest market segment, the solar home systems and the other 5 market segments are not supported.

10.3.3 Other policies and strategies

The other policies and strategies listed under section 10.1.1 are essentially meant to address some of the challenges encountered by the industry and provided in chapter 9. They are generally fine but they can be enhanced and improved.

10.3.4 Observations and conclusion

The 2004 energy policy did not address PV explicitly but it was reasonably covered under the general other RE policies. Under this policy now coming to an end, initiatives such as Feed-in-tariff, grants to public institutions for PV installations and direct funding for grid-connect and mini-grid systems and tax exemption on PV modules were implemented. Distribution of free solar lanterns to targeted communities was initiated recently. Standards, codes of practice and PV regulations were introduced to level the playing field for practitioners and improve on quality and service delivery to consumers. Standardized training and certification schemes were also introduced. These were no mean achievement even though some policies were not implemented probably due to lack of resources and technical capacity.

The new policy aims to continue implementing policies and programmes that were initiated under the outgoing policy and at the same time address a number of challenges encountered by the industry during the implementation of the outgoing policy. The policy has said nothing about financing and taxation other than grants to public institutions to install PV systems for own use.

In conclusion, the new policy is broad but short on specifics on solar PV. A few key recommendations follow hereunder.

10.4 Key policies, strategies and regulatory gaps and recommendations

i) Review of the feed-in tariffs scheme

- Both on-grid and off-grid have a minimum capacity set at 0.5MW. This capacity restriction locks out all other PV systems. Even the existing private mini-grids, which are fairly small do not qualify. The minimum capacities should be reduced substantially to accommodate small PV systems.
- The cumulative national capacity target is 200MW. This means only a few systems can be installed. It is not clear whether this limit includes the off-grid installations. The cumulative national capacity should be reviewed upwards but considering the national power development plans and PV impacts on the system.
- The tariff does not consider captive power producers who may have excess capacity that can be fed into the grid. Currently, these producer-consumers (prosumers) feed

the grid with excess power for free. There is a lot of interest and potential in this country for roof top PV investment. The tariff scheme should be revised to accommodate prosumers both residential, institutional and industrial through either net-metering or export tariffs or wheeling or banking, etc. or a combination of various possibilities all targeted at different segments.

- The tariffs are flat across the country. They do not consider the solar resource availability and intensity across geographical locations. This over-compensates investors who are located in regions with high insolation while under-compensating those located in regions with low insolation. The tariff does not differentiate between firm and non-firm power discouraging the use of energy storage. A review should be undertaken to differentiate tariffs by solar resource availability at site and also firm and non-firm power to encourage energy storage.

ii) Review and clarify taxes on PV BOS components and PV generated electricity

The new policy has avoided mentioning this issue but it's a major impediment to affordability. It also impacts on the government programmes – they cost much more. There is also lack of clarity on application as the interpretation differs between agencies.

It is recommended that this sticking issue be reviewed with a view to making it clear so that all agencies understand what taxes to levy on what products and services. Better still, a review with the aim of removing taxes on these components would go a long way in increasing affordability and enhancing industry growth.

iii) Financing and Investment support for PV

The new policy has avoided the issue of financing altogether save for the grants to public institutions and provision of free solar lanterns to targeted communities. Yet financing and investment support are key to success of PV markets. This was also a major challenge identified by the industry during the survey.

There are various financing models that have been used to support PV markets. The most common are grants and subsidies, equity, debt and asset financing models. There are several variants and sources of these forms of financing including international organizations such as the World Bank, development banks, commercial banks, MFIs, Saccos, etc.

It is recommended that the government develops PV specific financing and investment support schemes with a view to facilitating the private sector and PV consumers to invest in PV systems.

iv) Set PV capacity targets

One major drawback of the policy is lack of PV capacity targets to be achieved within the policy timeframe. Without targets in the policy, the industry can not undertake effective long-term investment planning, more so for private investors. PV targets should be set at national and regional levels to spread investments across the country. Furthermore, off-grid and on-grid capacity targets should be set separately.

v) Develop SHS and Stand-alone incentive schemes

The current tariff is beneficial to investments aimed at grid-connection only. The policy has ignored solar Lanterns, Plug and Play SHS, Stand-Alone PV, street lights and solar pumping. Yet these would have greatest national impact.

It is recommended that incentive schemes targeted at stand-alone PV systems be developed.

vi) Enforce existing regulations and standards

The industry has identified poor enforcement of standards and regulations already in place as one major setback for the industry. The consequence of this state of affairs has been proliferation of counterfeit products, poor and non-performing PV installations and entry of substandard PV products and services into the market. Efforts should be redoubled to ensure effective enforcement of existing standards and regulations.

vii) Review administrative processes and procedures for the PV sector.

Even though some guidelines were prepared together with the introduction of feed-in tariffs, it is felt that they are in-adequate to cater for the emerging market segments and approaches to the identification of projects. For example, energy auctions have been mentioned to replace existing un-competitive investor led processes. Tax exemption on PV BOS is another area of confusion.

To avoid such situations, administrative processes should be reviewed to address challenges identified earlier and introduce new and efficient approaches for project identification all the way to approval and implementation covering all market segments.

viii) Timely implementation of policies and strategies

As stated earlier, the new policy is broad but short on specifics on solar PV. Whereas this is not necessarily bad because it gives room for wide interpretation and application, it creates room for doing very little especially where there are resource constraints and lack of creativity or interest on the part of the implementers.

Good policies are of no use if they are not implemented. But experience has shown that Kenya is very good at making policies but poor at implementing them. This is the only reason we are emphasising that timely implementation here.

ANNEXES

ANNEX 1

SURVEY QUESTIONNAIRE

1. Introduction

1.1. Background Information (for interviewees briefing)

The Energy Regulatory Commission (ERC) is the energy sector regulator, with responsibility for economic and technical regulation of electric power, renewable energy, and downstream petroleum sub-sectors, including tariff setting and review, licensing, enforcement, dispute settlement and approval of power purchase and network service contracts.

The commission is mandated to, among others: -

i) Regulate the importation, production, distribution, supply and use of renewable and other forms of energy;
ii) Protect the interests of consumer, investor and other stakeholder interests.
iii) monitor, ensure implementation of, and the observance of the principles of fair competition in the energy sector, in coordination with other statutory authorities;
iv) Provide such information and statistics to the Minister as he may from time to time require;
v) Collect and maintain energy data;
vi) Prepare indicative national energy plan;
vii) perform any other function that is incidental or consequential to its functions under this Act or any other written law.

ERC has not undertaken any PV industry study in Kenya. Yet, according to the latest Kenya Integrated Household Budget Survey (KIHBS) of 2015/2016, 14.1 % of households in Kenya use PV for lighting. This means that PV contributes significantly to the countryφs household fuel mix.

To execute its mandate of data collection and maintenance, ERC has engaged Rencon Associates Ltd, a Renewable Energy and Energy Efficiency Consultancy Firm to undertake a study of solar PV industry market in Kenya.

The overall objective of the study is to assess the current status of the solar photovoltaic industry in Kenya, establish quality capacity and performance of installed systems, identify barriers and regulatory gaps that hinder the growth of the industry and recommend measures to enhance the uptake of the technologies in the country. The data and information obtained from the study shall provide valuable input in the formulation of policies and regulations whose primary goal will be to create a conducive and enabling PV business environment to enhance PV sector development.

Your organization, being one of the key players in the industry, has crucial market information and we seek your participation in this survey, which is greatly appreciated.

Rencon guarantees that any data and information provided by you shall be kept strictly confidential and shall **NOT** be disclosed to parties other than ERC and shall only be used for the purposes of the survey.

1.2 Purpose of the Interview Questionnaire

This interview questionnaire is a data capture tool that will guide Rencon during the survey. It will be filled by Rencon engineers in face-to-face interviews.

2. Particulars of the Organisation/Institution

Name of Company/Organization	
Address	
Email Address	
Names of Interviewee	
Designation of the Interviewee	
Telephone number of Interviewee	
Name of Interviewer/s	
Date of the Interview	
Any other relevant detail	

PART 1: Business Enterprises Questionnaire

This part to be used on organizations and companies conducting PV business in Kenya

1. When did you start PV business line? é ..

2. What is the nature of solar PV business? Pick those that are relevant to your business in the table below.

Business Type	Manufacturer	Importer /Wholesaler	Distributor	Dealer/ Retailer	Consultant	Technician
Your nature of business (tick relevant ones)						

3. How many employees do you have dedicated to the PV business?

4. **4.** Is solar PV your core business line (that gives you more than 50% of your turnover) é é Kindly provide us with your PV Business Turnover over the last 5 years. Use table below.

	Annual Turnover (KShs)	Percentage contribution to companyôs Total annual turnover (%)
2017		
2016		
2015		
2014		
2013		

5. What PV products do you market? Select products relevant to you in the table below.

PV Products	PV Panels	PV Batteries	Charge Controllers	Inverters	Solar lanterns	Lighting Kits (packaged)	Solar home systems (customized)
Marketed							

by your company (yes/no?)							
PV Products	Solar Pumps	Large Institutional Systems (customized)	Gri-Tie systems	Mini-grid systems	Services (installation and repair)	Common appliances (e.g. lamps)	Other (state) (e.g. Street Lights)
Marketed by your company (yes/no)							

6. Who supplies you with the main PV components/products? If direct imports, please indicate supplier/manufacturer and country of origin for each of the products. Record the information in the table below.

PV Products	**Manufacturer**	**Manufacturer Country**	**Supplier (if not manufacturer)**	**Supplier Country**	**Remarks about supply/ier**
PV Panels					
Charge Controllers					
Inverters					
Batteries					
Solar Pumps					
Lights					
Other (state)					

7. What are the sizes/capacities/ratings, prices and sales volumes of main PV components and load appliances, such as Panels, inverters, batteries etc? Choose and complete appropriate tables for the products applicable to you among the tables below.

PV Panels

Make/Manufacture									
Country									
Power rating									
Technology type (X/A-Si, etc)									
Voltage									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. sold 2012									
No. sold 2011									
No. Sold 2010									

PV Batteries

Make/Manufacture									
Country									
Capacity (AH)									
Voltage									
Technology (Lead Acid, Alkaline, etc)									
Packaging (Sealed, Vented)									
Cycling ability (poor/good?)									
Price/unit (KShs)									
Sales/month or sales/year									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. Sold 2012									
No. sold 2011									
No. sold 2010									

Charge Controllers

Make/Manufacture									
Country									
Current rating (A)									
Voltage rating									
Type (Standard/MPPT?)									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. Sold 2012									
No. sold 2011									
No. sold 2010									

Inverters

Make/Manufacture									
Country									
Power Rating (W/kW)									
Input Voltage (V)									
Type (Pure Sinewave/ Modified Sinewave)									
Grid-Tie ability (yes/no?)									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. Sold 2012									
No. sold 2011									
No. sold 2010									

Solar Pumps

Make/Manufacture									
Country									
Power Rating (W/kW)									
Input Voltage (V)									
Type (Borehole/Surface)									
Pumping Head									
Flow rate (Litres/hour)									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. Sold 2012									
No. sold 2011									
No. sold 2010									

Solar Lamps

Make/Manufacture									
Country									
Power Rating (W)									
Type (CFL, LED, LED Tube, Fluoro Tube)									
Voltage (V) and type (DC/AC?)									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. Sold 2012									
No. sold 2011									
No. sold 2010									

Solar Lanterns

Make/Manufacture									
Country									
Power Rating (W)									
Type of lamp (CFL, LED bulb, LED Tube, Fluoro Tube)									
Voltage (V)									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									
No. Sold 2012									
No. sold 2011									
No. sold 2010									

8. What are the ratings, capacities, prices and sales volumes of off-the shelf integrated packages you market? This are DIY type of kits. Provide data in the table below.

Package name /Kit (e.g D-light 30)					
Panel Rating (W)					

No. of Lamps (W)					
Phone charging? (yes/No?)					
TV use (yes/no?)					
Price/Unit (KShs)					
No. Sold 2017					
No. Sold 2016					
No. sold 2015					
No. sold 2014					
No. Sold 2013					
No. Sold 2012					
No. sold 2011					
No. sold 2010					

9. Have you put together standard SHS packages that you offer your customers? If yes, What are ratings, capacities, prices and sales volumes of these standard packages you market? These are complete kits that have to be installed by a technician. They may be DC or AC.

Brand/Name/Description					
Panel Power (W)					
Battery Size (AH)					
Charge Controller included? If yeas rating (A)					
Inverter Included? If yes rating (W)?					
No. of Lamps (W)					
Phone charging? (yes/No?)					
TV use (yes/no?)					
Other uses allowed (state)					
Price/Unit (KShs)					
Estimated Installation Cost (Kshs)					
No. Sold 2017					
No. Sold 2016					
No. sold 2015					
No. sold 2014					
No. Sold 2013					
No. Sold 2012					
No. sold 2011					
No. sold 2010					

10. Do you offer custom-designed institutional systems. Kindly provide data and information on power range quantities and prices of customized systems you have sold over the last 8 years in the table below.

System panel Power range (W)	50-100	100-200W	200-300W	300-500W	500-1000W	Above 1000W
Average Panel power (W)						
Average Battery Size (AH)						
DC or AC?						
Typical uses (e.g. lighting)						
Average Price/system (KShs)						
Estimated Installation Cost (Kshs)						
No. Sold 2017						
No. Sold 2017						
No. Sold 2016						
No. sold 2015						
No. sold 2014						
No. Sold 2013						

No. Sold 2012						
No. sold 2011						
No. sold 2010						

11. Do you offer Street Lighting packages. Kindly provide data and information on power range quantities and prices of street lighting packages you have sold over the last 8 years in the table below.

System Power capacity (W)						
Average Battery Size (AH)						
DC or AC?						
Typical uses (e.g. lighting)						
Average Price/system (KShs)						
Estimated Installation Cost (Kshs)						
No. Sold 2017						
No. Sold 2017						
No. Sold 2016						
No. sold 2015						
No. sold 2014						

No. Sold 2013						
No. Sold 2012						
No. sold 2011						
No. sold 2010						

12. Do you offer Minigrid and grid-tied systems? Kindly provide data and information on power range, quantities and prices of mini-grid, grid-tied systems you have sold over the last 5 years in the table below.

System panel Power range /capacity (W)					
System type (MG/HB/GT?)					
Batteries included (y/n?)					
If Hybrid, the other generator (DGset/Wind etc?)					
No. of customers served					
Typical uses (e.g. lighting)					
System cost materials (KShs)					
Installation Cost (Kshs)					

No. Sold 2017					
No. Sold 2016					
No. sold 2015					
No. sold 2014					
No. Sold 2013					
No. Sold 2012					
No. sold 2011					
No. sold 2010					

13. Do you offer solar pumping systems? If yes, kindly provide us with data on capacities, head, performance, prices and sales volumes over the last 8 years.

Make/Manufacture									
Type (Borehole/Surface)									
Power Panel capacity (W/kW)									
Pumping Head									
Flow rate (Litres/hour)									
Price/Unit (KShs)									
No. Sold 2017									
No. Sold 2016									
No. sold 2015									
No. sold 2014									
No. Sold 2013									

No. Sold 2012									
No. sold 2011									
No. sold 2010									

14. Over the years, who have been your major customers for the various systems described in the last 5 questions. Pick three customers who buy and indicate either number 1, 2 or 3. No. 1 buys most and No. 2 follows with No.3 being the one who follows No.2 in purchasing PV systems. Also indicate approximate percentage

	Private Individuals	National Governments Institutions	County Governments	Development Partners and NGOs	Private Institutions
Solar Lanterns					
Packaged Lighting Kits					
Custom-designed PV systems					
Large Institutional PV systems					
Solar pumps					
Min-grids					
Grid-Tie PV systems					

15. You have been in business for many years now and you have been installing and maintaining PV systems. This survey would like to know from you how the systems you have sold have performed over they years. Kindly rate the performance of your systems by picking the level of performance you have gathered from your customers in the table below. Indicate approximate percentage of your customers that that level of performance.

System performance description	Good	Satisfactory	Poor
Performance rating (tick)			
No. of your Customers reporting (%)			

16. For the systems that performed satisfactorily or poorly. What were the most common causes of their poor performance?. These could be component failure, poor installation, misuse/overuse, lack of maintenance/servicing, etc.

	Common causes of poor/unsatisfactory performance of systems
1	
2	
3	
4	
5	

17. Of the 5 main components of PV systems (Panel. Battery, Charge Controller, Inverter, Lights), which components are responsible for system poor performance or failure and how often? Tick one most applicable option for each component in the table below.

Component	**Component responsibility for system failure/poor performance**		
	Most failures	**Few failures**	**Least/No failures**
Solar Panel			
Solar battery			
Charge Controller			
Inverter			
Lights			

18. In year 2012, The Energy (Solar Photovoltaic Regulations) 2012 were put in place to regulate solar photovoltaics energy products and systems market in the country. The regulations put in place relevant processes and procedures for proper conduct of PV business including

licensing, training and certification of technicians, systems design and installation, quality control etc., requirements of all practitioners and stakeholders in the PV industry in Kenya to ensure quality products and services are offered to the customers and also encourage accountability. Comparing the period before 2012 and after 2012, do you agree that the regulations have achieving the intended impacts.

Impact of the Regulations	**Agree Strongly**	**Agree**	**Disagree**	**Disagree Strongly**
Brought order in the PV market				
The quality of PV products and components available in the market has improved				
The installation quality of the systems has improved				
Systems performance has improved				
Reported systems failures and malfunctions have gone down				

19. Over the years, a number of institutions and consultants have been offering technical training to PV practictioners and technicians? Do you think the industry is now well stocked with adequately trained, qualified and skilled and manpower to provide competent PV services? (Yes/No?) é é é é .

20. If the answer to 18 is NO, what skills have not been well addressed for the PV industry? Listed in the table below are required skills at various levels. Indicate those that are lacking in the PV industry in Kenya in the table below.

Management/Professional level competency skills adequacy in Kenya

Skill	**Skills available (yes/No?)**	**Skills Adequate? (Yes/No) in terms of numbers for the industry**
Business modelling		
Feasibility studies and project evaluation		
Raising finance and Risk analysis and management		
Design, installation, testing and commissioning, operation and maintenance of stand-alone PV power systems		
Design, installation, testing and commissioning and operation and maintenance of mini-grids and grid-tie systems		

Technicians/Artisan level competency skills adequacy in Kenya

Skill	Skills available (yes/No?)	Skills Adequate? (Yes/No) in terms of numbers for the industry
Installation, testing and commissioning, operation and maintenance of stand-alone PV power systems		
Design, installation, testing and commissioning and operation and maintenance of mini-grids and grid-tie systems		

21. How do you finance your supplies?

	Business Financing
Cash	
Supplier credit	
Bank loans	
Other financial institutions (Saccos, MFIs)	
Other	

22. How do most of your customers finance their PV systems?

	Finance sources	% of your customers using this source of finance for their PV systems
Cash		
Supplier credit (instalments)		
Hire purchase		
Bank loans		
Other financial institutions (Saccos, MFIs)		
Other (state)		

23. In year 2012, Solar PV regulations were published. The Regulations covered mainly licensing and certification of manufacturers/ vendors/ contractors and technicians to ensure that customers get value for money and get properly designed, installed and performing systems.

a) So far, have these regulations served the purpose of improving the quality and performance of PV systems and services offered to clients? é é é é é .

b) Have they aided or hindered the growth of the PV industry? é é é é é é

c) Do you think the industry has grown faster because of the regulations or the regulations slowed the growth?

24. The role of government and regulatory agencies in creating enabling business environment through appropriate policies, laws and regulations need not be emphasised. What EXISTING government policy interventions do you think are hindering the rapid growth of the PV industry in Kenya? List in table below.

	Existing policy/regulations that are hindering rapid PV industry growth
1	
2	
3	
4	
5	

25. In the PV industry what does the government and regulatory agencies need to put in place to enhance the growth of the sector and increase uptake of PV products and services? List 4 government interventions you consider crucial whose impact would transform the sector. List in table below.

	Recommended Government policy and/regulatory interventions to transform the PV industry
1	
2	
3	
4	
5	

26. What other challenges do you face and how do you propose they be addressed and by whom?

	Challenges faced in your PV business	Proposed action to address it and by whom?
1		
2		
3		
4		

27. Do you have any remarks and/or recommendations you would like to make about local PV industry?

PART 2: KEY INFORMANT INTERVIEW QUESTIONS

1. What is the recognized status of your operations in Kenya? Tick in Table below

Status	Gov. Agency/Ministry	Industry Association	Int. NGO/Dev Agency	UN Agency	World Bank Agency/Project	Local NGO/CBO	Other
Your Status							

2. What is the nature of your engagement in the PV Industry in Kenya? List below key activities you undertake in the PV industry in Kenya.

	Key activities
1	
2	
3	
4	
5	

3. For how long have you been engaged in the PV industry in Kenya?

4. How many employees do you have devoted to the PV sector activities?

5. What motivated your organization to get involved in the PV industry in Kenya?

6. Please rate your success in undertaking your above activities and achievement of your objectives.

Success rating	**Very good**	**Good**	**Satisfactory**	**Poor**
Tick one				

7. What challenges have you faced or observed in undertaking your above activities in Kenya. Describe them.

	Challenges
1	

2	
3	
4	
5	

8. Does your organization operate in any other countries and are you involved in PV industry in those countries?

9. If yes to above question, kindly share your experiences and compare with Kenya, touching on PV industry policies, regulations, standards, incentives, taxation, skills availability, access to financing, marketing and promotion etc.

10. Do you have any other key recommendations you would like to make about local PV industry to enhance the uptake of PV products and services? Recommendations may be to government and business enterprises.

	Recommendations
1	
2	
3	
4	
5	

PART 3: END-USER QUESTIONNAIRE

1. When was your system installed? Year é é é é é é ..

2. Who financed your system? é é é é é é é é ..

3. Who installed it (Contractor)? é é é é é é é ..

4. You have been using PV systems for many years. This survey would like to know from you how the systems you have been using have performed over the years. Kindly rate the performance of your systems by picking the level of performance in the table below.

System performance description	Good	Satisfactory	Poor
Performance rating (tick)			

5. For the systems that performed satisfactorily or poorly. What were the most common causes of their poor performance? These could be component failure, poor installation, misuse/overuse, lack of maintenance/servicing, etc.

	Common causes of poor/unsatisfactory performance of systems
1	
2	
3	
4	
5	

6. Of the 5 main components of PV systems (Panel. Battery, Charge Controller, Inverter, Lights), which components have been responsible for system poor performance or failure and how often? Tick one most applicable option for each component in the table below.

Component	**Component responsibility for system failure/poor performance**		
	Most failures	**Few failures**	**Least/No failures**
Solar Panel			
Solar battery			
Charge Controller			

Inverter			
Lights			

7. Who is responsible for servicing and maintenance of your PV system? é é é é é é é é

8. Is there an annual budget for servicing and repair of your systems? Yes/No? é é é é é

9. How often do you have the system serviced/maintained per year? Once/Twice ? é é é ..

10. Who carries out the maintenance work? Licensed Contractor/Electrician? Local technician? Staff?......................

ANNEX 2

REFERENCES

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11 Snapshot of Global photovoltaic Markets 2018 report by International Energy Agency (IEA)
12 Fraunhofer ISE: Photovoltaics Report, updated: 19 June 2018
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14 PV status report 2017 Joint Research Centre, European Commission
15 Lighting Global/ GOGLA Offgrid Solar Market trends report, January 2018.
16 Feasibility Study on the Introduction of Sanyo Solar Led Lanterns and Solar Charging Stations In Kenya, UNDP, 2011.

Annex 3

Stakeholders Interviewed

Business Enterprises

No	Name Stakeholder	Name of Interviewee	Email Address
1	Suntrasffer	Robert	Info@Suntransferkenya.Com
2	Dream Ep Global Energy	Japheth Mutungi	Info@Dream-Kenya.Com
3	Power Options Limited	Partick Ogesi	Info@Poweroptionsltd.Com
4	Harmonic System Co Ltd	Mark Muinde	Mark@Harmonicafrica.Com
5	D Light	Peter Odedo	Peter.Odedo@Dlight.Com
6	Power Group Technologies Ltd	Patrick Muoki	Info@Powergroupte.Com
7	Transafrica Water	Charles Lumumba	Info@Transafricawater.Com
8	Delta	Richard N. Nyangau	Richard.Nyangau@Deltaenerg
9	Mobisol Kenya Limited	Recardo	Jambo@Plugintheworld.Com
10	Daima Energy	Samuel Maranga	Enquiries@Daimaenergy.Co.Ke
11	Telesales Solar	Enos Otieno Orongo	Enosotieno@Gmail.Com /Solar@Telesales.Co.Ke
12	Dynavolt Technology(K) Ltd	Ndinda Mutuku	Markinliu@Gmail.Com
13	Solargen Power	John Kiama Mbugua	John@Solagenpower.Co.Ke
14	Asachi Limited	Charles Mutuku	Info@Asachi.Co.Ke
15	Center For Alternative Technology	Dennis	Operationsclerk@Cat.Co.Ke
16	Hyperteck Electrical Services Ltd	Mwoya J Patrick	Info@Hyperteckelectricalservice
17	Aston Field	Bhuvikumar Chovatiya	Ashan@Astonfield.Com

18	Go Solar		
19	Sollatek Electronics Ltd	Walid Khodabaksh	Walid.Kd@Sollatek.Co.Ke
20	Powerpoint Systems E.A Ltd	Joseph Munywa	Infor@Powerpoint.Co.Ke
21	Triple-S- Solar Ltd	Nabil Abamjee	Nabil@Tripple-S-Solar.Com
22	Davis & Shirtliff	Norman Chege	Norman.Chege@Dayliff.Com
23	Orb Energy	Angellah Wekongo	Kenya@Orbenergy.Com
24	Chloride Exide K Ltd	Karanja Njoroge	Cs@Chlorideexide.Com
25	Solinc East Africa	Keneth Mbugua	kmbugua@solinc.co.ke

Key Informants

	Name of Stakeholder	Type of institution	Interviewee
1	MINISTRY OF ENERGY	Government Ministry	Eng. Kiva
2	Lighting Africa Project	World bank Project	Nana Asamoa
3	Strathmore University	University	Geoffrey Rono
4	Practical Action	Int. NGO/Dev. Agency	Elizabeth Njoki
5	GIZ	Int. NGO/Dev. Agency	Walter Kipruto
6	WISEe	Energy Cooperative Society	TAMEEZAN
7	SNV Netherlands	Int. NGO/Dev. Agency	Victor Githogo
8	KPLC	Gov. Agency	Henry Kapsowe
9	KEREA	Industry Association	Cliff Owiti
10	REA	Gov. Agency	Eng. Muriithi
11	Kenya Association of Manufacturers	Industry Association	Elijah Esabu

Public Institutions on PV systems Performance – Internet survey

County	Public Institution	Contact address
Kitui	Ilaani Primary School	ilaaniprimaryschool@gmail.com
Kitui	Isevini Primary School	charlesmbiti100@gmail.com
Kajiado	Nkuyan Adams Primary School	eshokore@yahoo.com
Kajiado	Oloibortoto Primary School	elijahlaoi@gmail.com
Kitui	Tii Primary School	mbwarujohnmurovo@yahoo.com
Kajiado	Ilkiremisho Primary School	burugugeorge6@gmail.com
Kilifi	Matolani Primary School	mwambegu60@gmail.com
Kajiado	Lemasusu Primary School	olekutata2014@gmail.com
Kajiado	Enosampumpur Primary School	enoosprimary@yahoo.com
Homabay	Kinchororio Primary School	dominicndate@gmail.com
Homabay	Ringiti Primary School	luganosamwel864@gmail.com
Kitui	Kilawa Dispensary	domitiliamwangangi@gmail.com
Homabay	Nyalkembo Primary School	oumaeucabet@yahoo.com
Homabay	Ponge Primary School	obogeouma@gmail.com
Kitui	Kikuuni Primary School	petronilakitonga@yahoo.com
Kitui	Mbuvo Primary School	kiambajoseph15@gmail.com
Kitui	Mutitu Sub County Hospital	gistereros@gmail.com
Kilifi	Kapecha Primary School	lilianmwatua5@gmail.com
Kilifi	Kirosa Primary School	cosmaskatana8@gmail.com
Kajiado	Mitamimisyi Primary School	johnkimunga@gmail.com
Kilifi	Mgamboni Pry School	fkalisho@gmail.com
Kitui	Kilawa Dispensary	domitilamwangnagi@gmail.com
Homabay	Riwa Primary School	tombasquel12@gmail.com
Kitui	Kyenini Primary School	muriungistephen2017@gmail.com
Kitui	Endau Secondary School	endausecondary@gmail.com
Kajiado	Olkiramatian Dispensary	wesleysnips24@yahoo.com
Kilifi	Kadaina Community Dispensary	pmwafondo@gmail.com
Kajiado	Enkolili Primary School	wilsonnarasha@gmail.com

Counties interviewed and have Streetlights.

County	Contact Person/Source of data	Number of Solar Street Lights
Baringo	Hon John Tarus(MCA)	147
Bungoma	Mr Michael Ngunyi	400
Busia	Devolution conference magazine 2018, pg 102	170
Elgeiyo Marakwet	Hon Cheboi(CO)	210
Embu	County government webside, department of energy	170
Homabay	County government webside, department of energy	650
Kajiado	1st governors report card 2018 , pg 7	295
Kakamega	Joseph Sweta CO Planning	30
Kiambu	Eng. Nicholas Mbogo	55
Kilifi	Mr Baya Wilfred	263
Kisii	Eng. Oyaro Matoke, Devolution conference magazine 2018 pg113	796
Kitui	Rachael Mwangangi(CEC)	800
Kwale		358
Lamu	Alex Jimbi(CO infastructure)	199
Makueni	Eng Musyoki Josphat	44
Mandera	Devolution conference magazine 2018	1854
Marsabit	Marsabit County CADP 2018/2019	417
Meru	county office number	0
Migori	Ayogo Tobby	600
Muranga	Eng. Mangodu	60
Nakuru	Eng Ngeno(CEC)	654
Nyamira	Eng. Hezron Otwori(roads)	1202
Nyeri	County Director Energy	20
Siaya	Siaya County CIDP workshop on March 13th 2018	341
Taita Taveta	A Mjomba	383
Tana River	Mohammed Mwatunza	50
Tharaka Nithi	Samuel Gaicura (CEC trade)	15
Trans Nzoia	Hon Nambafu(CEC)	50
Turkana	Lotuko Sospeter	930
Uasin Gishu	Uasin Gishu county CIDP 2018-2022, pg 16/217	256
Vihiga	TENDER NO: T& INF/VCG/TENDER 0049/2015-16,	30
Wajir	Muhemed Jehow	912
	Total	**12361**

ANNEX 4

POLICY BRIEF

- Detached Document

ANNEX 5

TERMS OF REFERENCE

- Detached Document